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MOIRS OF THE GEOLOGICAL SURVEY,
SCOTLAND.

THE ECONOMIC GEOLOGY
OF
THE CENTRAL COALFIELD OF SCOTLAND,

PRESENTED BY HIS MAJESTY'S GOVERNMENT

DESCRIPTION OF AREA II.

INCLUDING THE DISTRICTS OF

DENNY AND PLEAN; BANKNOCK; CARRON AND GRANGEMOUTH; CUMBERNAULD; CASTLE-CARY AND BONNYBRIDGE; FALKIRK AND SLAMANNAN.

BY

L. W. HINXMAN, B.A., F.R.S.E.; C. B. CRAMPTON, M.B., C.M.;
E. M. ANDERSON, M.A., B.Sc.; and M. MACGREGOR, M.A., B.Sc.,

WITH CONTRIBUTIONS BY

THE LATE C. T. CLOUGH, LL.D., F.R.S.E.

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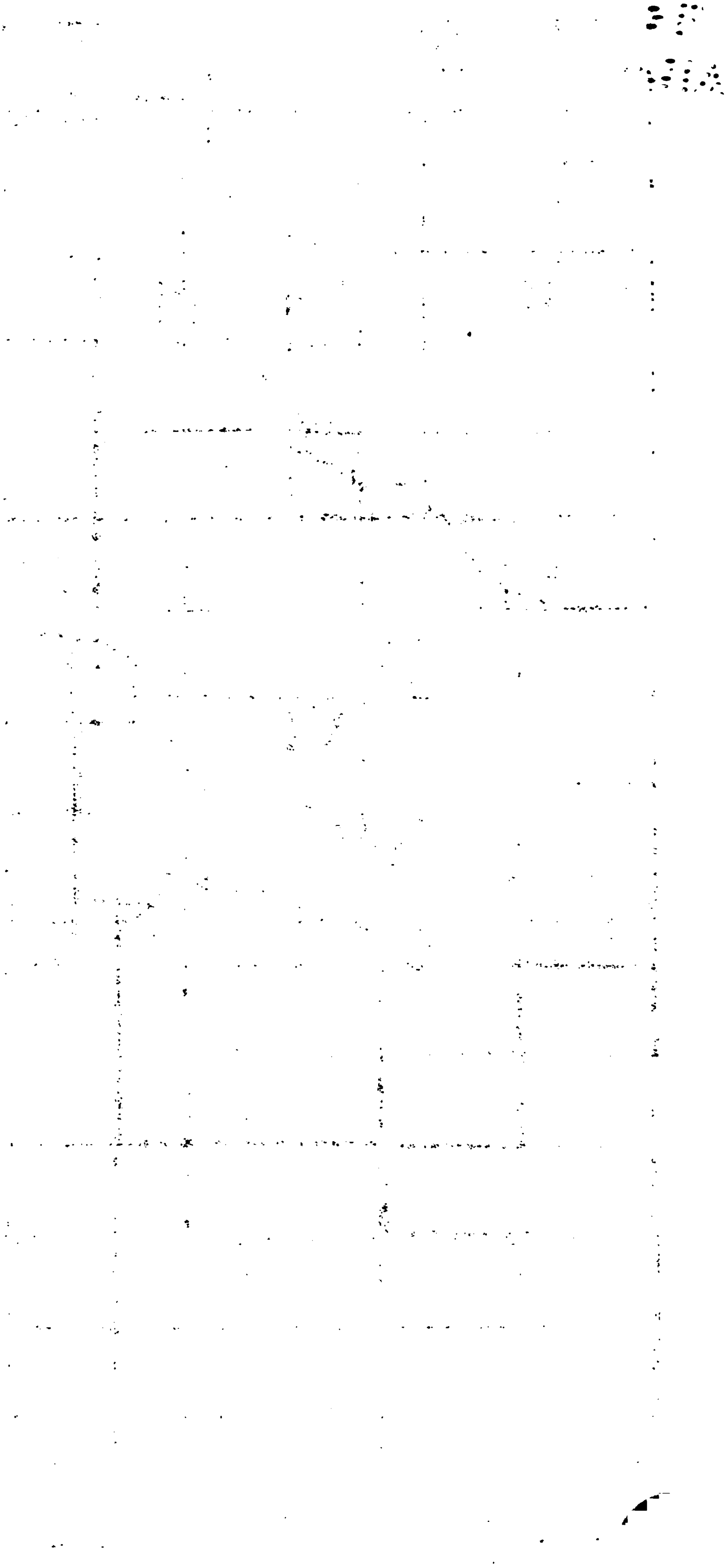

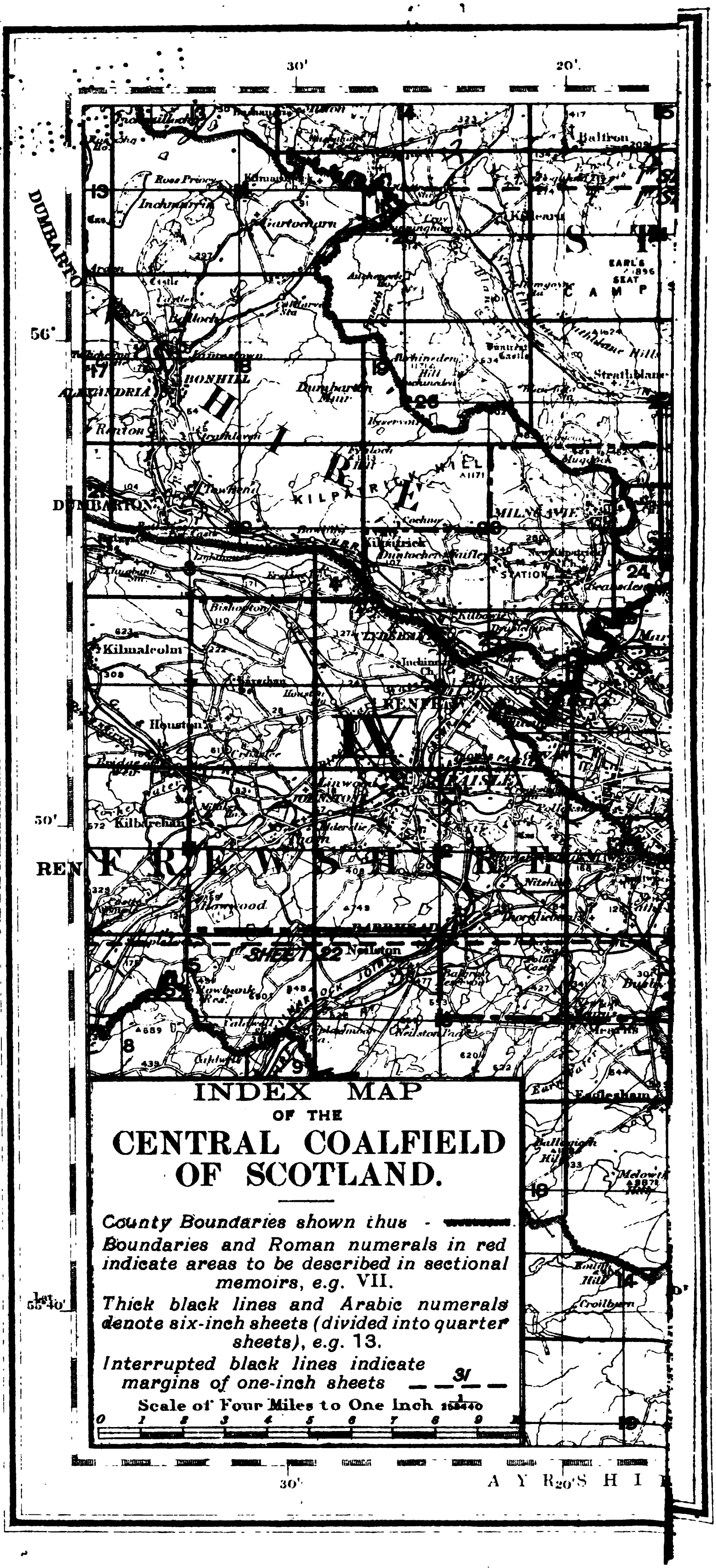

INDEX MAP
OF THE
CENTRAL COALFIELD OF SCOTLAND.

County Boundaries shown thus -

Boundaries and Roman numerals in red indicate areas to be described in sectional memoirs, e.g. VII.

Thick black lines and Arabic numerals denote six-inch sheets (divided into quarter sheets), e.g. 13.

Interrupted black lines indicate margins of one-inch sheets 31

Scale of Four Miles to One Inch $\frac{1}{253440}$

0 1 2 3 4 5 6 7 8 9

MEMOIRS OF THE GEOLOGICAL SURVEY,
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PREFACE.

THIS Memoir is the third of the series dealing with the economic geology of the Central Coalfield of Scotland to be published. It deals with the second of the nine areas into which the Central Coalfield of Scotland is divided for the purposes of geological description. Area II., as will be seen by the Index Map which forms the Frontispiece, includes the north-eastern corner of the one-inch Sheet 31, with a small part of Sheet 39, and lies almost wholly within the County of Stirling. Several important fields, in which coal and fireclay are being mined, fall within it.

The greater part of the district was originally surveyed in 1869–71 by Dr. B. N. Peach: the remaining small areas of Linlithgow and Lanarkshires by [Sir] Archibald Geikie and the late [Prof.] James Geikie. The geology of that part of the area which is included in Sheet 31 was described in the Explanation of that Sheet, published in 1879.

The revision, of which the results are given in the following pages, was carried out in the years 1904–1910, the distribution of the work having been as follows:—the Plean, Denny, Banknock, Carron, Grangemouth and Airth coalfields by Dr. Crampton; Falkirk and Slamannan by the late Mr. J. S. Grant Wilson and Mr. E. M. Anderson; the Cumbernauld, Castlecary and Bonnybridge districts by Mr. Hinxman; the small area east of the river Avon by the late Dr. C. T. Clough; and the marginal strip of coal measures in the south-west by Mr. R. G. Carruthers.

The Memoir has been edited by Mr. Hinxman. The thanks of the Survey are due to the officials of coal and fireclay mining companies, mining engineers, and others, not specially mentioned in the body of the Memoir, for valuable assistance rendered during the progress of the revision.

Pressure of work, due to the War, has delayed the completion of the geological maps of the area described. They will be issued at the earliest possible date.

A. STRAHAN,
Director.

GEOLOGICAL SURVEY OFFICE,
28 JERMYN STREET, LONDON, S.W.,
7th February 1917.

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In pocket at end of Volume.

UNIV. OF CALIFORNIA

THE ECONOMIC GEOLOGY OF THE CENTRAL COALFIELD OF SCOTLAND.

AREA II.

(The six-inch Maps included in this Area are as follows :—Stirling, 23 N.E., S.E. ; 24 N.W., N.E., S.W., S.E. ; 25 N.W., S.W. ; 29 N.E., S.E. ; 30 N.W., N.E., S.W., S.E. ; 31 N.W., S.W. ; 34 N.E. ; 35 N.W., N.E. ; 36 N.W. ; Linlithgow, 1 N.W., S.W. ; 4 S.E. ; 5 N.W., S.W. ; Lanark, 3 N.W., N.E.)*

CHAPTER I.

INTRODUCTION.

THIS Memoir forms one of a series which it is proposed to publish in description of the geology—mainly from the economic point of view—of the Central Coalfield of Scotland, which includes not only the whole of the Lanarkshire coal basin but also portions of the counties of Renfrew, Dumbarton, Stirling, Linlithgow and Edinburgh. Within it is contained the whole of one-inch Sheet 31 together with parts of Sheets 22, 23, 24, 30 and 39. The Plate forming the frontispiece shows the division of the Central Coalfield into separate areas for descriptive purposes, each area having an individual Memoir. It also indicates the boundaries and numbers of the revised geological six-inch Quarter Sheets contained in each area.

The Index Map (Fig. 1) shows, on a larger scale, the area about to be described, with the included six-inch Quarter Sheets and the surface area occupied by the chief geological formations.

The area described in the following pages extends from Plean and Airth Castle in the north to Fannyside Muir, Slamannan and Avonbridge in the south. It includes the Limestone Coals and ironstones of Denny and Plean ; the valuable fireclays and ganisters of Castlecary, Bonnybridge and Glencryan, and the Coal Measure fields of Banknock, Carmuirs, Carron and Grangemouth, Airth and Falkirk. For descriptive purposes the whole of the Slamannan† coalfield lying within the county of Stirling is also included, although some of this field falls within the adjacent area, V.

---

* The Fife area on the north side of the Forth is not referred to in this Memoir.

† The village of Slamannan, at one time a great mining centre, does not actually lie within the coalfield to which this name has for convenience been given.

GENERAL STRUCTURE OF THE AREA.

Area II. falls within the north-eastern extension of the Lanarkshire basin, the axis of the fold extending almost due north from Slamannan to the Forth near Kincardine. This axis, however, lies considerably nearer to the eastern than the western margin of the district under description: consequently on the western limb of the syncline the greater part of the Carboniferous Limestone Series and the whole of the Millstone Grit are represented, whereas on the eastern side of the basin only small parts of these formations come within the area.

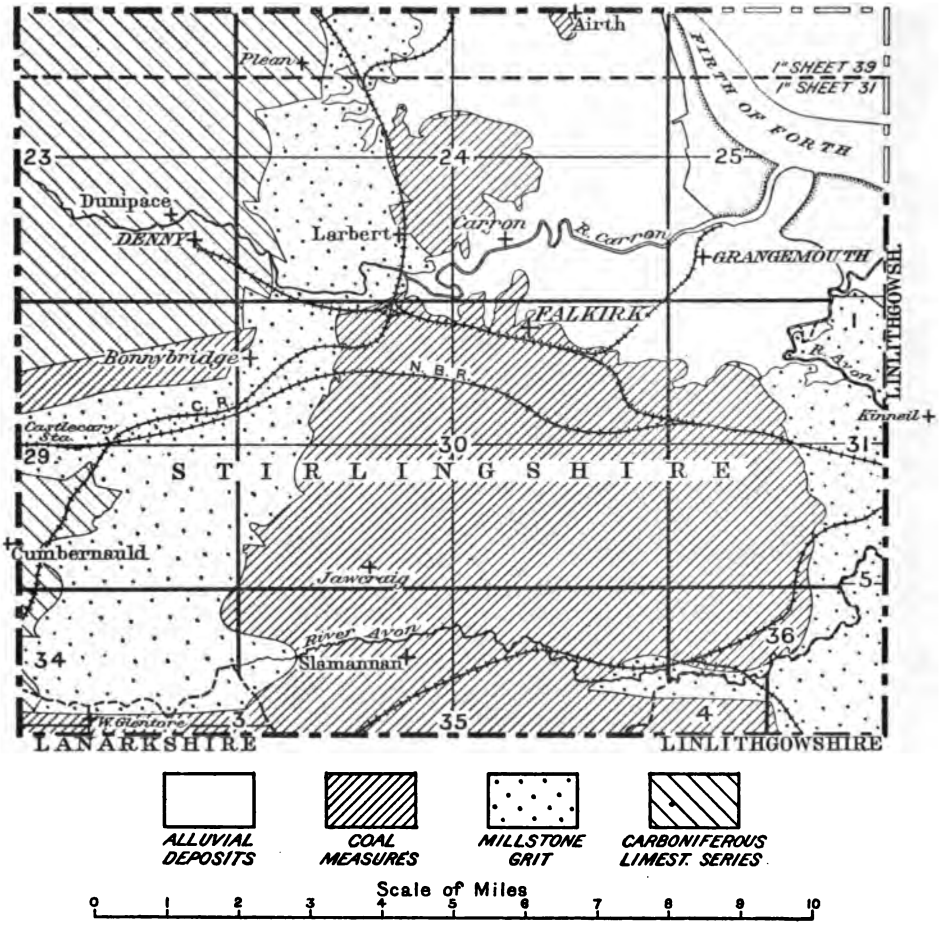

FIG. 1.—Index Map of Area II.

A dominant feature in the structure of the ground to the north of

Falkirk is the powerful fault, with downthrow to south, which branches from the Campsie fault between Kilsyth and Banton and traverses the area in an easterly direction to the Forth at Grangemouth. Another fault, with a contrary throw to the north, diverges from the former dislocation near Low Banton, and, after running parallel with it for several miles, joins it again at Kerse Bridge, west of Grangemouth. Between these two faults lie the Banknock Coal Measure outlier and the Carmuirs coalfield.

The area further to the north, between Denny and the Forth, is also crossed by a series of more or less continuous lines of fracture with an approximate east and west direction. The downthrow of these faults is in most cases to the south, and the outcrops of the Coal Measures and Millstone Grit are in consequence stepped successively to the west, the displacement caused by the fault which passes north of Torwood and Kinnaird amounting to upwards of a mile.

On the north-west margin, the Carboniferous strata, including the southern prolongation of the Stirling dolerite sill, overlap on to the volcanic rocks of the eastern end of the Campsie Hills, and it is doubtful whether any Calciferous Sandstone sediments exist within the area. L. W. H.

The most important structural feature of the southern part of the area is connected with the Lenzie-Torphichen whin dyke. This dyke separates the Slamannan from what for purposes of description will be termed the Falkirk coalfield. The latter is taken as including the mining districts of Polmont, Brightons, Muiravonside, Shieldhill, Jawcraig and Bonnyhill, as well as the immediate neighbourhood of Falkirk.

The dyke referred to follows, and probably rose along a line of dislocation, with downthrow to the south of at one point about 40 fathoms. It apparently acted as a feeder to whin floats which branch off from it at different levels on its northern and southern sides. That to the south is intruded into Coal Measures, and affects at different places various of the workable seams. It underlies the whole of the Slamannan coalfield, and rises to the surface in a range of low hills which stretch southwards from Avonbridge. On the northern side the intrusion occupies in one place a horizon a little above the Index Limestone, and probably never rises higher than the base of the Millstone Grit. It is likely to be present beneath all the southern part of the Falkirk coalfield, but at too great a depth to affect the Coal Measure seams. Further reference will be made to this sill in the pages dealing with concealed areas of the Limestone Coals, Chap. II. p. 18.

Coinciding with this dyke, or lying slightly to the north of it, is the axis of an anticline running east and west, or at right angles to the direction of the main syncline. Its effect is seen in bringing the Millstone Grit along the Avon valley to the west of Avonbridge.

A similar east-and-west anticlinal fold separates the subsidiary basin of the Falkirk coalfield from that of Carron and Airth in the north. The continuity of these folds is, however, in some degree interrupted by the Banknock trough fault already referred to.

E. M. A.

A narrow strip of Coal Measures along the northern border of the Greengairs coalfield falls within the south-western margin of Area II. The Coal Measures are here faulted down against the Millstone Grit to the north by a line of dislocation, which, to the east of Fedderland, follows the Lenzie-Torphichen dyke. L. W. H.

CHAPTER II.

CARBONIFEROUS LIMESTONE SERIES.

Denny and Plean.

(Stirling, 23 N.E., S.E.; 24 N.W., S.W.; 29 N.E.)

ALMOST the whole of this district is occupied by the members of the Carboniferous Limestone and Millstone Grit Series, which stretch northwards across the area from the boundary-fault of the Banknock Coal Measure outlier in two parallel bands of varying breadth.

The general strike of the beds approximates to north and south, the dip is easterly, and the angle of inclination highest in the west, in the neighbourhood of the overlap on to the volcanic rocks; eastwards the diminishing angle of dip causes the outcrops of the Upper Limestone Group to be considerably broader than those of the lower members of the Series in the west.

The continuity of the outcrops is interrupted by a series of large faults which traverse the area with a general east-and-west trend.

The largest of these dislocations passes north of Carbrook House to Woodcockfauld, where it appears to branch into a number of minor faults, all, like the main line of fracture, throwing down to the south. This fault shifts the outcrops of the upper limestones for nearly a mile to the west, and forms the boundary between the Plean and Quarter coalfields. A short distance to the north, a fault with a contrary downthrow to north runs east immediately south of Plean House, and, crossing the Stirling road at Plean village, turns to the north-east. The northerly throw of this fault at Plean House is not more than 6 fms. but increases rapidly in the direction of Carnock.

C. B. C., L. W. H.

Recent mining operations have added largely to our knowledge of the rocks of this district, and the sequence of strata in the two upper groups of the Carboniferous Limestone Series, as well as in the overlying Millstone Grit, is far better known than at the time of the original survey, more than fifty years ago. This additional information has been chiefly derived from the deep diamond bores and pit shafts put down in recent years in the Plean area by the East Plean Colliery Company. To the courtesy of the officials of that Company and, in particular, to the kindness of Mr. Wallace Thorneycroft, we are indebted for access to the journals and cores of the borings, and for much other general information embodied in the following pages.

We have also been permitted to publish graphic detailed sections of the three principal bores in the Plean district, and of the pit shaft at the Plean colliery. (See Plates IV.-VI.) L. W. H.

For information regarding the Denny coalfield we are indebted to Messrs. Addie & Sons, Herbertshire Colliery; also to Mr. R. T. Moore, C.E., for details concerning the abandoned workings on the Castlerankine estate.

LOWER LIMESTONE GROUP.

Concerning the rocks of this group not much is known; they reach their greatest development in the ground west of Drumbowie and Castlerankine, and also occur to the west of Plean, but in the Denny and Dunipace district their position at the surface is occupied by contemporaneous and intrusive igneous rocks. Two thin limestones are seen in the River Carron, a short distance above Carron Grove Mill; the lowest of these, a 2-ft. band with marine fossils, was considered by Dr. Crampton to represent the Blackhall Limestone of the Glasgow district. Lines of old workings along the Chough Glen and above the stream at High Quarter, north and east of Quarter House, indicate the outcrop of a dark encrinital limestone, probably repeated by faulting, which may be regarded as one of the Hosie Limestones of the Lower Group. M. M.

LIMESTONE COAL GROUP.

The Denny and Dunipace coalfield is geographically intermediate between that of Banton and Kilsyth to the south-west, and those of Plean and Bannockburn to the north-east. While, however, the general sequence remains the same throughout, the Limestone Coal Group is much thinner and contains fewer workable seams than that either of Kilsyth or Bannockburn. In the Denny and Plean district the thickening of the strata from west to east takes place chiefly in the succeeding Upper Limestone Group (see p. 19), but at Rosehill, on the east side of the Plean coalfield, and further north in the direction of Carnock, the increase in the thickness of the beds below the Index becomes well marked, the distance from that horizon to the Main Coal being at least 30 fms. greater than in the Denny field. (See comparative vertical sections, Plates IV.–VI.)

GENERAL SECTION OF LIMESTONE COAL STRATA IN THE DENNY DISTRICT.

Index Limestone.

		Fms.	Ft.	In.
Strata, mainly fakes and fireclay, with, locally, thin coals		6–7	0	0
COAL (foul), generally thin	6 in. to	0	2	0
Strata, sandstones and fakes		4–5	0	0
COAL, foul	up to	0	1	2
Strata, sandstones and fakes, with some fireclay and blaes	av.	15	0	0
UPPER DENNY BLACKBAND IRONSTONE		0	0	2–9
Strata, mainly sandstones, with thin coals near top		8	0	0
LOWER DENNY BLACKBAND IRONSTONE		0	0	5–9
Strata, fakes and fireclay	(about)	1	3	0
„ nearly all sandstone		11	0	0
COAL	a few inches			
Strata, chiefly fakes	(about)	1	2	0
COAL		0	1	3
Strata, sandstone over blaes	(about)	1	3	0
COAL	10 in. to	0	1	3

		Fms.	Ft.	In.
Strata, sandstone	(about)	2	0	0
COAL	up to	0	1	0
Strata, sandstone over fakes	(about)	4	0	0
„ blaes (with mussel-rib in one bore)		0	3	0
„ fakes and blaes		3	3	0
STEAM COAL (in two leaves)	(about)	0	2	8
Strata, fakes	very variable, say	0	4	0
MAIN COAL		0	1	4
Strata, faky sandstone	(about)	5	3	0
KNOTT COAL (with parting)		0	1	6
Strata, chiefly sandstone		6	0	0
„ "Black Metals"		9	0	0
Strata, chiefly fakes and sandstones		17	0	0
COAL (KILSYTH COKING position ?)	a few inches to	0	1	3
Strata, fakes, sandstones and blaes	(about)	20	0	0
„ with a few thin coals		4	0	0
„ mainly faky sandstones		9	0	0
COAL		0	0	10
Strata, fakes and sandstones		12	0	0
„ fakes and blaes, with IRONSTONE ribs.		11	3	0

Top Hosie Limestone.

While the sequence from the Steam Coal to the 15-in. seam (Kilsyth Coal ?), 38 fms. below, is fairly well known, the section beneath that horizon is less reliable, being based on incomplete data.

On comparing this section with that of the adjoining Plean coalfield, given below, it will be observed that the chief point of difference lies in the absence of the Denny Blackbands in the latter sequence and the occurrence of workable coal seams at Plean at about the same horizons; this variation is further discussed in the detailed description of the several seams, p. 16.

At the present time (1916) coal is being raised in the Denny district only at the Herbertshire Colliery, Nos. 2 and 3 Pits, where the Steam Coal is worked.

The Quarter Colliery pits, working the Bannockburn Main Coal, were abandoned in 1911.

The East Plean Colliery Company are now working the Lower 20-inch and Bannockburn Main seams in the Plean district.

M. M.

GENERAL SECTION SHOWING THE PRINCIPAL HORIZONS OF THE LIMESTONE COAL GROUP AT PLEAN COLLIERY.

Index Limestone.

	Fms.	Ft.	In.
Strata, with thin coals	9	0	0
sandstones, fakes and thin fireclays	29	0	9
COAL	0	1	2
Strata, sandstone	2	0	0
COAL, UPPER 20-inch	0	2	3
Strata, blaes, fireclays and thin coals	8	0	0
COAL, LOWER 20-inch	0	1	11
Strata, sandstones and fakes	6	0	0
COAL	0	1	0
Strata, chiefly sandstone	5	0	0
MUSSELBAND	0	3	3½
Strata, blaes	1	4	0
STEAM COAL	0	2	6½
Daugh	0	1	3
MAIN COAL	0	2	0

	Fms.	Ft.	In.
Strata, sandstones and fakes	10	0	0
COAL, foul. KNOTT (thickens to N. and E.)	0	0	2
Strata, fakes and sandstones	6	0	0
Black Metals	7	0	0
IRONSTONE—BANTON CLAYBAND.	0	1	0
Strata, fakes and blaes	14	3	0
IRONSTONE and COAL (with partings)	0	1	4
Strata, fakes	4	0	0
COAL, KILSYTH COKING?	0	1	4
Strata, fakes and sandstone			

The detailed description of the Limestone Coal Group in the Denny and Plean area is as follows:—

The Top Hosie Limestone, the highest member of the Lower Limestone Group, is followed in upward succession by a series, approximately 14–15 fms. in thickness, of blaes with thin ribs of clayband ironstone. Hence to the local equivalent of the Kilsyth Coking Coal the distance is about 44–45 fms.; occupied chiefly by fakes and sandstones, with several thin coals and blaes with clayband ribs.

Kilsyth Coking Coal:—The seam correlated with this elsewhere valuable coal does not appear to be of workable thickness anywhere in this area, and, as recorded in several borings in the Denny field, rarely exceeds 12 inches, and is generally less. Two bores on Castlerankine, 300 yds. apart, give the following sections:—No. (1) coal, 11 in.; No. (2) coal, 15 in.; ironstone, 1 in.; coal, 13 in.; parting, 1 in.; coal, 2 in.

Section (2) seems, however, to be quite exceptional in the thickness of the seam.

Bores on the East Plean estate show that the coal thickens towards the east, but does not exceed 18 in.

At No. 4 Pit, Plean, it is 16 in.; an analysis of the washed and dried cores gave the following result:—

COKE	Fixed Carbon	74·81
	Sulphur	·79
	Ash	2·75
VOLATILE MATTER	Hydrocarbon	21·28
	Sulphur	·37
	Moisture	...
		100·00

This coal cannot be regarded as a coking coal.

The Kilsyth Coal was at one time wrought in the long since abandoned Milton Grove Pit, situated near the point where the Stirling-Glasgow road crosses the Bannock Burn, a mile and a half beyond the northern margin of Area II. The section at this pit was said to be—

		Ft.	In.
	Fakes and blaes	3	0
KILSYTH COKING COAL	COAL	1	9
	Sclit holing	0	6
	COAL, coarse	0	9
	Faky blaes	1	0
	Sandstone		

The distance separating the Kilsyth Coal position from the base of the "Black Metals" varies from 17 fms. at Castlerankine to 19 fms. at Plean No. 4 Pit. The strata consist mainly of fakes and sandstones, but in the lower part several bands of blaes with ironstone ribs appear. In the Denny field there are four of these horizons: 2, 5, 7 and 10 fms. respectively above the Kilsyth Coal. The third is in one case recorded as an 11½-in. blackband: otherwise the ribs appear to be claybands.

In the Plean section a horizon with two clayband ironstone ribs overlying a 10-inch coal occurs at 4 fms. above the Kilsyth Coal position.

Black Metals.—This group, as elsewhere, forms a series of dark blaes, 7 to 12 fms. in thickness, with ribs and seams of clayband ironstone throughout, but most abundant in the lower part of the group. The thickest clayband lies one or two fms. above the base; it is recorded as 2 ft. 6 in. at Upper Thomaston; 2 ft. 1 in. at Bowridge; 10 in. to 15 in. at Castlerankine; and 1 ft. at Little Denny. In No. 4 Pit, Plean, this horizon is represented by 3 ironstones—2 in., 1 ft., and 3 in.—it is here correlated with the Banton Clayband Ironstone.

A band with marine fossils (Productus, etc.) was passed through in the Carbrook Mains No. 1 Bore, 3 fms. above the base of the Black Metals.

Four to seven fathoms of strata, almost entirely fakes and sandstones, with, locally, a thin coal close above the top of the Black Metals, separate that group from the next named horizon, the *Knott Coal.*

This seam is best developed in the extreme northern part of the Plean district. A small area of the coal was wrought prior to 1884 on the estates of West Plean and Auchenbowie. The following section of the seam was measured in 1895, in a blind pit sunk 5 fms. from the Main to the Knott Coal at a point 200 yds. east from Auchenbowie Gate Lodge, and 700 yds. W.N.W. of West Plean House.

	Strong roof	
KNOTT COAL	COAL	10 in.
	Dirt	4 "
	WILD COAL	2 "
	COAL	15 "
	Hard pavement	

Analysis of the two leaves of the seam gave:—

		TOP COAL.	BOTTOM COAL.
COKE	Fixed Carbon	50·50	60·34
	Sulphur	2·25	2·14
	Ash	23·00	12·50
VOLATILE MATTER	Hydrocarbon	23·10	22·73
	Sulphur	·52	·41
	Moisture	·63	1·88
		100·00	100·00
	Total Sulphur	2·77	2·55
	" Phosphorus	·048	·082

Crushing and washing would have reduced the amount of ash, and a hard coke could be made from the coal, but the sulphur and phosphorus contents would be unusually high.

A considerable area of this seam was also formerly wrought from Mackison's Pit, 700 yds. to the north, near the junction of the Roman Road with the main Stirling-Glasgow road. The section here was said to be—

Blaes roof	
Stone	18 in.
Coal	14 „
Dirt	6 „
Coal	18 „

On the East Plean estate the seam becomes very thin: a series of bores between Muirmailing Farm and No. 4 Pit show that the position is here represented only by a few inches of coal. Further to the east the seam again thickens.

The seam representing the Knott Coal position in the Denny area is not of workable thickness: it is usually split into two thin leaves, separated by blaes or coaly fakes. At Castlerankine the section shows—Foul coal, 8 to 13 in.; coaly fakes, 6 to 7 in.; coal, 7 to 9 in. On Blaefaulds—Coal, 14 in.; fakes, 5 in.; coal, 11 to 15 in. In some places no coal is recorded in this position.

The strata between the Knott and the Main Coal vary in thickness from 6 to 10 fms.: they are chiefly fakes and sandstones, with locally one or two thin coals of a few inches each.

The Bannockburn Main Coal.—This valuable seam, the equivalent of the Cloven Coal of Kilsyth, occurs throughout the Denny and Plean area in three leaves, separated by "dirt" or "stone" partings of varying thickness. To these leaves different names have been given in the different collieries as below:—

Carronrigg.	Herbertshire.	Quarter.	East Plean
1. Main Coal	1. Steam Coal.	1 Main Coal.	1. Top Coal (Steam).
2.	2.	2	2. Mid „
3.	3. Pavement Coal or Bannockburn Main.	3.	3. Bottom Coal or Bannockburn Main.

At Carronrigg, where the seam was wrought under the name of the Main Coal up to the year 1906, sections at four localities in the old workings give—

	1. Near Woodhead.	In.	2. E. of Castlerankine Farm.	In.	3. A little N. of No. 1 Pit.	In.	4. Near Blaefaulds.	In.
Main Coal	Coal	9–10	Coal	11	Coal	12	Coal	11–13
	Stone	7	Dirt	10	Dirt	12	Dirt	24
	Coal	14–15	Coal	17	Coal	17	Coal	14–16
	Stone	8			Dirt	18		
	Coal with rib	18			Coal with 1½ in. rib	17½		

The Carronrigg Colliery yielded a steam and smithy coal of excellent quality.*

At a point about 550 ft. slightly east of north from No. 2 Pit, the coal was found to be burnt; the burnt coal was traced for 300 yds. in a direction somewhat S. of E. It proved unworkable, and was said to have shown columnar structure: at least one patch of good coal, however, occurred within the affected area, showing the burning to be irregular. South of the 10 fms. east and west fault, at No. 2 Pit, the Main Coal has been worked and found in good condition between the crop and a line drawn south of the pit: it has not been wrought to the east of that line, where it is probably burnt.

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* See Dron, "Coalfields of Scotland," p. 172

To the south of Castlerankine the coal becomes thinner, an average section in the Drumbowie ground reading as follows:—

	In.
Coal	9
Dirt	12–13
Coal	12–14
Dirt	5–20
Coal	5–6

Passing to the Herbertshire Colliery workings, where the Steam Coal is still being raised, we find in the more westerly part of the field, near the old Blaefaulds ironstone pit, a section very similar to that of Carronrigg. In the east, however, at Herbertshire No. 3 Pit, the lowest leaf is separated from the steam or upper coals by several feet of fakes, and is known as the Pavement Coal.

A recent section in the Herbertshire Steam Coal workings, close to the site of the old Blaefaulds No. 1 Pit, shows—

	In.
Coal	14
Dirt	18
Coal	24
Dirt	24—thickening to east.
Coal	22

The Steam Coal of Herbertshire Colliery furnishes a navigation coal of high quality. The analysis is as follows:—

		No. 1*	No. 2*
Volatile Matter	Gas, tar, etc.	20·30	20·80
	Sulphur	·30	·25
	Water	1·28	1·10
		21·88	22·15
	Fixed Carbon	73·71	72·95
	Sulphur	·39	·90
	Ash	4·02	4·00
		78·12	77·85

The heating power is given in Analysis No. 2 as 10·16 lb. of water at 212° F. evaporated by 1 lb. of coal.

The coal gives off little flame or smoke, but does not coke readily.

In the Plean area, the bottom leaf of the Bannockburn Seam is now the principal coal wrought, under the name of the Bannockburn Main Coal. Near the outcrop, on the west side of the field, the coal is only 18 to 22 inches thick, but is very good in quality. Separated from the Main Coal by a band of dark sandy fireclay of varying thickness is another seam of inferior coal, 18 to 20 inches thick, with numerous thin dirty partings.

* No. 1 by Wm. Wallace, Glasgow, 1885; No. 2 by Messrs. Tatlock and Thomson, 1902.

The thickness of the coals increases eastwards to the dip, and is accompanied by a constant variation in the thickness and character of the intervening "dirt" bands.

This variation in the character of the seam in different parts of the Plean district is graphically shown in the diagrams (Fig. 2, and Plate II.), for which we are indebted to Mr. Wallace Thorneycroft. Fig. 2 gives the section of the whole seam in the now abandoned Quarter Colliery, at a depth of about 200 fms. and some 1¾ miles east of the outcrop.

Between the Bottom Coal, or Bannockburn Main Coal of Plean, and the rock pavement is a bed of fireclay with two inches of dirty coal next the rock. The mid "dirt" parting has at the bottom a band of hard "stone," variable in thickness and sometimes absent altogether. The top band of dirt, separating the two upper leaves of coal, thins out to the north and passes into a bed of dirty coal, which thickens to the north and becomes the Mid Coal of the East Plean workings.

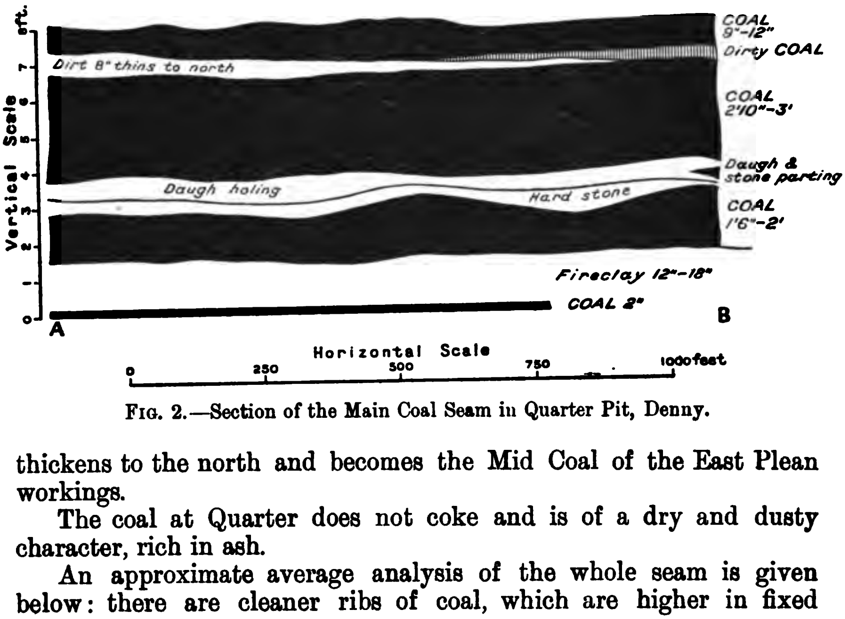

FIG. 2.—Section of the Main Coal Seam in Quarter Pit, Denny.

The coal at Quarter does not coke and is of a dry and dusty character, rich in ash.

An approximate average analysis of the whole seam is given below: there are cleaner ribs of coal, which are higher in fixed carbon.

Moisture	1·2
Volatile Hydrocarbon	16·8
Fixed Carbon	70·0
Ash.	12·0
	100·0

Plate II. shows the section of the seam in the northern part of the Plean workings. Starting near the outcrop on the Plean estate, north of Woodcockfauld, it extends north-eastward through No. 3 and No. 4 Pits, and thence east by south in the direction of Pleanmill.

The Cowie Pit shaft section is also given in order to show the further change to the north, just beyond the limits of the present area.

The Bottom Coal, or Bannockburn Main Coal proper, rests upon hard sandstone with a thin daugh parting sometimes increasing to 6 or 8 inches. This coal is somewhat soft, with a cubical fracture: it proved very suitable for smithy purposes and for coking; the average analysis is as follows:—

Moisture	1·5
Volatile Hydrocarbon	26·5
Fixed Carbon	68·0
Ash	4·0
	100·0

This Bottom Coal has been worked for many years past near the crop, and the ready supply of a good smithy coal accounts for the numerous small forges at one time found in the neighbouring villages, where, during the last century, hand-made nails and all kinds of light wrought-iron work were produced. This industry has now died out owing to the competition of machine-made factory products.

The parting above the Bottom Coal is a dark, sandy, laminated fireclay which increases in thickness from D to E (Plate II.) and thence thins eastwards until at G it is represented by a thin, black, sandy rib.

Above this parting generally follows a soft, pliable and fairly clean coal, succeeded by a soft coal with numerous thin intercalations of black sandy sclit: this layer is often known as the Mid Coal. It sometimes contains bands of harder coal, very high in ash, known as "wild coal."

The average analysis of the Mid Coal between the points D and F is approximately as follows:—

Moisture	1·5
Volatile Hydrocarbon	16·0
Fixed Carbon	46·5
Ash	36·0
	100·0

The coal immediately above, worked as the Top Coal, is much cleaner, with only a few dirt partings and some "eyes." The average analysis of this band between D and F is—

Moisture	1·5
Volatile Hydrocarbon	24·5
Fixed Carbon	68·0
Ash	6·0
	100·0

When formerly filled together and picked as clean as possible, the Top and Mid Coals of this area contained about 18 per cent. of ash: thus, while they afforded a steam coal of good heating properties, the high ash content was prejudicial to its market value.

By a more recent process the coals are crushed together and passed through apertures of ⅜-inch diameter: the mixture is then washed in a specially designed machine which separates it into

(1) practically pure coal, with sp. gr. 1·3; (2) a comparative small quantity of the doubtful product, sp. gr. 1·4 to 1·6; and (3) dirt.

This result is quite satisfactory, and the coal thus treated affords a first-class metallurgical coke for by-product ovens.

The Top and Mid Coals contain an unusual amount of phosphorus which cannot be removed by crushing.

The roof of the seam is a strong blaes about 18 ft. thick, with a well-marked musselband near the top. It has been suggested that the excess of phosphorus in the underlying coal may possibly be connected with this shell-bed: a series of comparative analyses of coal-seams in proximity or otherwise to musselbands would, however, be necessary to determine the value of this suggestion.

In the Denny area a "mussel" rib was recorded in a bore at Blaefaulds, about 3½ fms. above the Carronrigg Main Coal: this is probably on the same horizon.

Beyond the point F (Plate II.), about 1000 ft. east 10° south of Plean No. 4 Pit, a further change takes place in the character of the seam.

The bands of "wild coal" increase in number and thickness, while two distinct dirt bands appear in the Mid Coal. Of these the upper soon dies out: the lower gradually thickens for a distance of 400 yds., and then rapidly increases to a thickness of 24 in., completely cutting out the Mid Coal. This parting continues to increase until at the point G, 2250 ft. east of F., it becomes 3 feet thick, with the result that the Top or Steam Coal is too far separated to be worked with the underlying coals.

The change in character of this parting begins a little to the east of the point F: the upper portion passes into a hard, black, sandy stone with coal streaks, while the soft fireclay or daugh gradually thins out until the lower layer of the Mid Coal is only separated from the Main Coal by a hard, sandy rib.

At the Cowie Colliery, nearly two miles to the north-east, the "dirt" parting has thickened to over 5 ft., while still further to the dip, at Carnock, the thickness of the strata separating the seams has increased to upwards of 21 ft.

In the southern part of the Plean workings—separated from the northern portion by a branch of the Auchenbowie fault, the coal is thicker, harder and cleaner than in the northern area, and quite different in character from that of the Quarter Collieries to the west.

To the south of Plean House the Main Coal is about 22 in. thick, and is a fairly hard bright coal with some "eyes" and a few pyrite balls. It is suitable for house and navigation use: many trial trips of famous boats were run with this coal: it also makes very good coke.

The average analysis of the seam in this area is—

Moisture	1·5
Volatile Hydrocarbon	24·0
Fixed Carbon	71·5
Ash	3·0
	100·0

The "dirt" band above the Main Coal is very similar to that described in the northern part of the area: it thins out to the east, and near Carbrook Mains is only 2 inches or less in thickness.

The Mid Coal south of Plean House contains another distinct dirt parting, which also thins out eastwards but comes in again immediately to the east of Plean village, where it underlies the "Wild Coal," which in this part of the field takes the place of the upper part of the Mid Coal.

The average analysis of the whole of the Mid Coal, excluding the dirt parting referred to above, south of Plean House, was as follows :—

Moisture	1·5
Volatile Hydrocarbon	23·5
Fixed Carbon	60·0
Ash	15·0
	100·0

This coal was also crushed and washed.

The Top Coal in this part of the workings is a hard, bright coal with some "eyes": the average analysis—

Moisture	1·3
Volatile Hydrocarbon	23·7
Fixed Carbon	70·0
Ash	5·0
	100·0

Returning to the Denny area, we find the distance between the Steam or Top Coal and the next horizon of economic importance—the Lower Denny Blackband—to average from 24 to 25 fms. The upper part of the sequence is occupied by a thick sandstone which, in the absence of the blackband, forms a good index to its position. In the Plean area this sandstone is replaced by blaes with ironstone balls, fakes and fireclays. Below the sandstone is a group of fakes, sandstones and blaes, including three thin coal seams: the highest of these reaches 14 in. and lies about 11 fms. above the Main Coal. It is probably the coal met with in the Carronrigg Smithy Coal workings, and there known as the 14-inch Coal: it possibly also represents the Lower 20-inch Coal of Plean and Bannockburn.

The Denny Blackband Ironstones.—Two blackband ironstones, each lenticular and impersistent in character, have been wrought in the past in the Denny district. The lower band was raised south of the river Carron at Blaefaulds Colliery and Herbertshire No. 1 Pit; the upper in the area between Dunipace and Quarter; while both were wrought in the old pits of Messrs. Baird at Tygetshaugh. The Upper Blackband thus extended further to the north as a workable subject than the Lower, but when followed southward from Tygetshaugh the conditions were reversed. At No. 4 Pit, Tygetshaugh, the ironstones were approximately 8½ fms. apart, and gave the following sections :—

UPPER BLACKBAND	Fakes and blaes		LOWER BLACKBAND	Fakes and blaes,	4 ft. 6 in.
	WILD COAL	13 to 15 in.		Fireclay and balls	18 „
	IRONSTONE	2 to 9 „		IRONSTONE	5 to 9 „
	COAL	14 „			

The Lower Blackband lies at a depth varying from 32 to 38 fms. below the Index Limestone, in much the same position relatively to that limestone as the Main Possil Ironstone of the Cadder field, Glasgow. Like the blackbands of the Glasgow area, it is variable both in character and thickness, thinning out to a few inches round the edges of the field. The average section as proved in bores is as follows:—

PARROT COAL	2 to 4 in.
IRONSTONE	6 to 16 „
PARROT COAL	2 to 11 „

The lower seam of parrot varies as a rule inversely with the ironstone: it thins out on Little Denny, and further south the whole seam appears to be represented by a 12-inch coal.

The section of the Upper Blackband at Tygetshaugh is given above: it was also raised in the Risk, Drimalier, Broomhill and Anchor Pits, and also in the Ingliston Mine, south of Low Quarter Mill.

In the Quarter area it shows—Coal (generally parrot), 8 to 10 in.; ironstone, 7 in; coal, 4 to 14 in.

Both north and south of the Dunipace Quarter area the Upper Blackband also appears to pass into a coal. In a small area opened out by a mine immediately south of Herbertshire Castle, the seam was found to be of a more coaly nature than at Tygetshaugh, while further to the south across the Carron river it becomes a 9–13-inch coal, and is not workable as an ironstone.

While it is evident that these blackbands—like the Possil Ironstones of the Glasgow area, with which they may be génerally correlated—pass laterally into coals, an exact correlation with any particular coal seam in adjoining fields is seldom possible. There is, however, good reason for the belief that the Greenyards 20-inch of Bannockburn and the Upper 20-inch of Plean are on approximately the same horizon as the Lower Blackband of Denny, while the coal wrought at Carronrigg under the name of the Carronrigg Smithy may here represent the Upper Blackband. Only a small area of the Carronrigg Smithy Coal was worked, and the seam showed—Coal, 12 in.; stone, 1 to 8 in.; coal, 12 in. Its distance above the Main Coal in the shaft of No. 1 Pit was 36 fms.

The Lower Twenty-inch Coal of Plean is worked over a considerable area on the Plean estate. It varies in thickness from about 22 inches under Plean village, decreasing westwards toward the outcrop. At No. 3 Pit it is only 16 inches thick and unworkable.

A hard, dark, sandy rib, ⅛ to ½ inch in thickness, is generally found in the upper part of the seam, and a variable band of clayband ironstone in the blaes above is worked along with the coal.

This seam furnishes a good coking gas coal, containing about 60 per cent. of fixed carbon.

The Upper Twenty-inch Coal, although extensively worked further to the north and east, where it is a good coking gas coal, is not a workable subject on the estates of East and West Plean or Quarter.

The section of the seam at No. 4 Pit, Plean is:—

COAL	11 in.
Dark fireclay	8 in.
COAL	8 in.

The coal is here of fair quality, with about 58 per cent. fixed carbon.

The intermediate band of dark fireclay seems to die out eastwards and become replaced by coal: westwards towards the outcrop the coals become thinner. L. W. H.; M. M.

FAULTS.

In addition to the large east-and-west faults referred to on p. 3, three N.W. and S.E. dislocations of considerable magnitude have been proved in the workings of the Steam Coal at the Herbertshire Colliery. The most westerly of these crosses the field from Little Denny to Meadowbank, and has a downthrow to N.E. of 35 to 40 fms. A mine has recently been driven through this fault to open up the Steam Coal on the S.W. side in the neighbourhood of the old Blaefaulds Colliery. The second fault runs a parallel course immediately south of Mydub, with a downthrow to south estimated as approximately between 30 and 40 fms. near Mydub farmhouse. A third fault with the same trend passes through Little Denny Paper Mill, and has an approximate downthrow to south of 40 fms.

In the abandoned Carronrigg Main Coal workings two east-and-west faults were proved. One of these crosses the field just south of No 1 Pit, with a downthrow to north of 20 fms.; the other, with a contrary throw of 10 fms., runs immediately north of No 2 Pit.

M. M.

IGNEOUS INTRUSIVE ROCKS.

Two east-and-west quartz-dolerite dykes have been proved in the Herbertshire Colliery workings. At Denny they are about 200 yards apart, and are inclined to the vertical at an angle of about 27°. Further to the west they approach one another, and probably coalesce before reaching the dolerite sill at Myot Hill. Beyond the sill this intrusion appears to be continued in the dyke which traverses the volcanic rocks of the Campsie Hills: eastwards the more northerly of the Herbertshire dykes continues across the Carron and Grangemouth coalfields to the Forth (see p. 60). Trough-faulting, to the amount of a few fathoms, has been proved locally along the course of these dykes at Denny.

A prolongation of the great intrusive sheet of quartz-dolerite which forms the Abbey Craig of Stirling extends across the northwest corner of the area to the Carron west of Denny, and is continued south of that river in a greatly attenuated form to Myot Hill. North of the Carron the outcrop of the sill is more than 1½ miles in width, but where it crosses the river it measures only 500 ft., widening out again considerably on Myot Hill.

The thickness of the intrusion appears to be variable: in the ground south of Stirling it is about 50 fathoms; at East Quarter, N.W. of Denny, the dolerite was pierced by a bore to a depth of 46 fms.

The sill rises somewhat in the metals towards the dip, thus showing its transgressive character, but along the outcrop is intruded at a fairly constant horizon a short distance above the Hurlet Limestone.

The intrusion met with on exactly the same horizon further to the west, on the margin of the Banton area, is no doubt the same sill, but to the south of Myot Hill at least one other sill appears at a higher horizon. This intrusion runs southwards to the northern boundary-fault of the Banknock coalfield, with a gradual transgression of the metals, rising from a position somewhat below the Black Metals to a horizon above the Main Coal. The "burnt" or "blind" coals of the southern part of the Carronrigg and Drumbowie fields may, no doubt, be attributed to the effects of this sill or offshoots from it. M. M.

EXTENSION OF THE LIMESTONE COALS BENEATH THE HIGHER CARBONIFEROUS STRATA OF THE AREA.

On the north-western margin of the area, where the Limestone Coals lie nearest to the surface, they have—as described in the preceding pages—been followed eastward from the crop beneath the overlying Upper Limestone and Millstone Grit, and there is still a large field further to the dip in which these coals might probably be profitably worked though at a greater depth.

The existence of workable Limestone Coals south of the Canal, in the Castlecary and Cumbernauld district, is a more doubtful matter. The Survey have no information with regard to any bores—if such exist—that have been put down to these seams within this part of the area. It may, however, be stated, from evidence obtained further to the west just beyond the margin of the area, that in the neighbourhood of Cumbernauld village a "whin float" or dolerite sill, with a thickness of 48 fms., lies 23 fathoms beneath the Index Limestone.

How far, and at what depth in the metals this intrusion extends eastwards into the Bonnybridge area, there is as yet no available evidence to show, but the presence of the sill would have to be reckoned with in any boring operations in this direction.

L. W. H.

Any attempt to prove or work the Limestone Coals beneath the deeper parts of the basin is likely to be deferred until a search has been made in the areas where these coals are nearer the surface. In making such an enquiry the following points would require to be considered:—

(1) A sill of dolerite probably underlies the whole of the southern part of the Falkirk Coalfield. In the deep bore put down about a mile to the west of Slamannan this sill was met with at a horizon slightly above the Index Limestone, and proved to have a thickness of not less than 20 fathoms; this sill is probably continuous, towards the west, with that of the Kilsyth Coalfield, while eastward it rises to the surface in the dolerite crags of Torphichen. It is there intruded at, or slightly above, the level of the Castlecary Limestone. It is probable that 20 fathoms is a very moderate estimate for the thickness of the sill, which is likely to exceed this figure over most of the southern part of the Falkirk Coalfield. It is, however, of importance to note that the surface exposures of the intrusion show a certain impersistence. The Torphichen sill dies out a little over two miles to the north of the village of that name, while the Kilsyth sill is thinning towards the north-east, and it may be reasonably inferred

that the underground connection of these two intrusions behaves in a similar manner. Thus a bore put down near the town of Falkirk would in all probability find the igneous rock to be thinner than two or three miles further to the south. In any case the sill lies probably above the Index Limestone over most of this district, and is thus rather an obstacle to sinking operations than a likely cause of deterioration in the seams themselves.

(2) Another consideration of importance is the extent to which the strata are likely to be replaced, as they are near Linlithgow, by contemporaneous volcanic lavas and agglomerates. In a bore near Little Mill, about a mile north-east of Linlithgow, practically the whole of the Limestone Coal Group is affected in this manner. These coals are worked beneath the foreshore for some distance to the west of Bo'ness, but in a bore at North Hainings—see p. 27 and Plates VII-IX.—everything beneath the Seven-Foot Coal is again replaced by volcanic material, showing that the area of replacement extends westwards from Linlithgow, and may possibly affect the underlying coals beneath a part of the Falkirk Coalfield. In view of this contingency, and of what has already been stated with regard to the dolerite, the most hopeful position for a bore to prove these lower coals would be to the west of the town of Falkirk. The thickness of strata between the Slatyband at the base of the Coal Measures and the Index Limestone may be taken as roughly about 250 fathoms. E. M. A.

UPPER LIMESTONE GROUP.

There are few surface exposures of the rocks of this Group within the Plean and Denny area. Of the principal horizons, the Index Limestone is seen in the River Carron, near Stoneywood Paper Mill, where it is a hard limestone, 3 ft. in thickness, with abundant *Productus latissimus.* The Bishopbriggs Sandstone has been wrought in Blackcraig Quarry, near Plean House. The Castlecary Limestone is poorly exposed in Torwood Glen and in old workings east of Donovan House; at the former locality the upper portion is a calmy fossiliferous blaes, followed above by an inferior oil-shale and fireclay. The occurrence of an oil-shale in this position has been recorded at many widely separated localities on either side of the Lanarkshire basin.

None of the intermediate limestones is visible at the surface.

Our knowledge of the rocks of this Group is therefore, like that of the Limestone Coal Group, chiefly derived from the shaft and bore sections already referred to on p. 5. Vertical sections of the Upper Limestone strata passed through in mining operations will be found on Plate V., at the end of the volume.

Consideration of these sections and of others in the area south of Denny shows that the strata of the Upper Group thicken eastwards from Plean and northwards from Denny in the direction of West Fife. Evidence obtained further to the south and east proves that this is merely a local exhibition of a wide-spread phenomenon affecting the Upper and Middle Groups of the Carboniferous Limestone Series, the strata thinning rapidly to the south and west from a line of maximum thickness in the south-west part of the County of Fife.

The local thickening of the Upper Limestone strata from west to east is expressed in the graphic sections given on Plate V.; it is also shown by the following figures:—

	DENNY.	CARBROOK.	ROSEHILL.
Calmy Limestone to Orchard . .	40 fms.	34 fms.	42 fms.
Orchard to Lyoncross . . .	19 „	27 „	30 „
Lyoncross to Index . . .	42 „	50 „	62 „
Calmy to Index . . .	101 „	111 „	134 „

It will be observed that the increase in thickness takes place in the beds below the Orchard Limestone: it appears to be mainly due to the thickening of the sandstones throughout the lower part of the sequence.

The *Index Limestone*, at the base of this Group, forms as a rule one bed, with an average thickness of 3½ ft., usually shelly at the top and base, with abundant large Productus of the *P. latissimus* type. The overlying blaes with limy balls is 14 to 30 ft. thick; the lower part contains marine fossils. The normal thickness of the succeeding *Bishopbriggs Sandstone* is 50 to 60 ft., but this and the next sandstone horizon, the *Cadgers Loan Rock*, are sometimes so largely developed as to occupy almost the whole of the interval between the Index Limestone blaes and the Quarry or Lyoncross Coal, the sandstones being only separated by thin partings of blaes or coal.

The Bishopbriggs rock has been worked for some time in the Blackcraig Quarry, Plean; it is a fine-grained, white sandstone, and affords a building-stone of good quality.

The Cadgers Loan rock is coarse and gritty, and somewhat felspathic: it often exceeds 60 ft. in thickness. In a normal section several thin coal and ironstone positions are found between this and the Bishopbriggs Sandstone below, and in the Rosehill bore a 15-inch impure limestone. One of these coals is probably on the horizon of the Chapel Green Coal of Kilsyth, but none of them exceeds 11 inches in thickness.

There are also several thin coals in the beds immediately above the Cadgers Loan Rock; the lowest of these, known as the *Quarry Coal*, reaches a thickness of 2½ ft. in the Denny area. It is probably the equivalent of the Lyoncross Coal of the Glasgow district. In the shaft of No. 3 Pit, Herbertshire Colliery, where the seam is 2 ft. thick, it passed erroneously as the Hirst Coal.

A thin limestone or calcareous shale, containing lamellibranchs and gasteropods, 3 to 5 fms. above the Quarry Coal, has been met with in Denny, and was passed through in the Rosehill bore, but is not recorded in all the sections: it may be correlated with the *Lyoncross Limestone.*

The *Orchard Limestone* position has been recognised in bores and shafts throughout the area. It is a shelly and often faky limestone about 2 ft. in thickness, and usually rests directly upon a thin coal or parroty blaes, followed, 4 or 5 fms. below, by dark blaes with *Lingula* and one or more clayband ironstones. Above the limestone is a considerable thickness of dark blaes with limestone and ironstone nodules—the *Orchard Blaes.*

The Orchard Limestone and Blaes have yielded the following fossils:—Crinoids, *Orthoceras*, *Glyphioceras*, *Euphemus urei*, *Euomphalus*, *Productus longispinus*, *P. costellatus*: fragments of lamellibranchs. Other thin limestones are met with between the Calmy and the Index, but comparison of bore sections in different parts of the area shows that these calcareous horizons are inconstant, and are apt to disappear when the thicker sandstones, such as the Cadgers Loan and Bishopbriggs, are well developed. The Calmy Limestone, here as elsewhere, closely overlies the Hirst Coals, but the thickness of strata separating the two horizons is somewhat greater than in the areas to the west.

The *Hirst Coals* are fairly well developed in this district, but increase rapidly in thickness from west to east. The Upper Hirst in the Denny fields measures only 7 to 13 inches, but is 2 ft. 9 in. at Carbrook, and reaches a thickness of 4 ft. 2 in. in the Rosehill bore. Similarly the Lower Hirst increases from 12–14 inches at Denny to 2 ft. 3 in. at Rosehill.

The Hirst Coals have not been wrought in this area.

The ferruginous and calcareous blaes immediately beneath the Calmy Limestone have yielded the lamellibranch *Edmondia punctatella*, a fossil characteristic of this horizon over a wide area, and therefore valuable as an index in boring operations.

The *Calmy Limestone* is well developed in this region. It usually consists of two, three, or sometimes four beds of impure limestone or calcareous shale, separated by blaes partings: the thickness of the whole seam in the Denny field is 4 to 6 ft., and increases eastwards to 7 and 8 ft. in the Plean district.

The Calmy Limestone is succeeded above by a great thickness of dark blaes, often measuring as much as 60 ft. Like the Orchard Blaes, the lower part contains limy nodules, the higher large balls of clayband ironstone. Near the top of this mass of blaes there is sometimes present a band of limestone, upwards of a foot thick, containing abundant brachiopods, including *Productus* and *Spirifer*.

The blaes themselves also contain an abundant marine fauna, amongst which the following forms have been determined by the Survey:—

Lingula mytiloides *J. Sow.*
Pugnax pugnus (*Mart.*).
Productus of *semireticulatus* type.
Edmondia transversa *Hind.*
Nuculana laevistriata (*Meek* and *Worthen*).
Protoschizodus fragilis (*M'Coy.*).
Ptychomphalina marcouiana (*Geinitz*).

From the Calmy Limestone the following fossils have been obtained:—*Serpulites*, *Orbiculoidea nitida* (Phill.); *Lingula mytiloides*, J. Sow.; *Productus longispinus*, J. Sow.

The blaes above the Calmy are followed by a considerable thickness of sandstones and fakes, with blaes partings.

Between the Calmy and Castlecary Limestones of this area there are three well-marked calcareous horizons containing abundant marine fossils. These were first established as a result of the examination by the Survey of the cores from borings put down by the East Plean Colliery Company; they have therefore been given the names of the *Plean Limestones*, 1, 2 and 3.

In the Carbrook Mains No. 3 bore, ⅞ miles east of Plean Church, where these horizons are particularly well developed (see Plate V.), the lowest band, Plean No. 1, lies 40 fms. above the Calmy Limestone. It is a shelly limestone, 2 ft. 5 in. thick, followed below by 7 in. of shelly blaes, and rests upon a thin coal position. The next band, No. 2, 24 fms. higher up in the sequence, consists of 15 in. of shelly limestone and 5 in. of limy blaes. It should be observed that this horizon, Plean No. 2, has not been detected in all the sections hitherto examined. Four fathoms above in the Carbrook bore is Plean No. 3, represented here by 8 in. of calcareous shelly blaes resting upon coaly blaes.

In the Rosehill bore, No. 1 is represented by shelly blaes with limy balls, 37 fms. above the Calmy; No. 3 by limy fakes, 16 in., 22 fms. below the Castlecary. The position of No. 2 is doubtful.

The fossils found in the two upper calcareous bands resemble those of the shales associated with the *Castlecary Limestone.*

The last-named limestone, the highest member of the Upper Limestone Group, has an average thickness of 2 ft. in the Plean district, but appears to thicken southwards towards Dunipace, where it reaches 4 to 5 ft. In the Carbrook bore it is a 20-inch limestone followed above and below by calcareous shelly blaes: at Rosehill the solid limestone is 2 ft., also between beds of limy blaes; the total thickness of the seam in each case is 3 ft. 5 in.

It is usually a light-coloured, somewhat crystalline limestone with encrinites. The overlying shales contain marine forms, among which are the following:—

Spirifer sp.
Leiopteria squamosa (*Phill.*).
Nucula gibbosa *Flem.*
Nuculana attenuata (*Flem.*).
Sanguinolites clavatus (*R. Eth.*).
Euphemus urei (*Flem.*).
Ptychomphalina marcouiana (*Geinitz*).
Orthoceras sp.

From the economic standpoint a knowledge of the strata of the Upper Limestone Group is chiefly of value as a guide in sinking bores or shafts to the coals and ironstones of the Limestone Coal Group below.

With the exception of the *Edmondia punctatella* blaes which underlie the Calmy Limestone, there are no horizons that can be said to be absolutely identifiable by the fossils which they contain. In spite of this fact, the importance of a proper examination of the cores of borings, both for their fossil contents and for the association and sequence of marine bands, coal positions, fireclays, sandstones, etc., can hardly be over-estimated. A comparatively short section of a core is sometimes sufficient to fix with certainty the position reached in the bore. C. B. C.

Castlecary and Cumbernauld.

(Stirling, 29 N.E., S.E.; 30 N.W., S.W.; 34 N.E.)

Rocks belonging to the Upper Group of the Carboniferous Limestone Series occupy a narrow, irregular belt along the south-western margin of this area between Castlecary and Glenhove.

This outcrop is interrupted at Glencryan by an east-and-west fault with downthrow to south, which shifts the base of the Millstone Grit westwards towards Greenyards, half a mile east of Cumbernauld Station.

The evidence afforded by a deep bore recently (1914) put down at the roadside, 700 yds. north of the Spur Inn, Cumbernauld, indicates that the approximate position of the outcrop of the Calmy Limestone lies just within the margin of Stirling, 29 S.W., and therefore outside the limits of the area under description. Almost the whole of the strata represented at the surface within this belt lie consequently above the horizon of the Calmy. In another deep bore near Cumbernauld Station, also just beyond the margin of Area II., the principal horizons of this Group were passed through in normal sequence. The Index Limestone measured 5 ft. 11 in.; the Orchard, 11 in.; the Calmy, in two bands, 5 ft. 10 in.: the distance between the Calmy and the Index amounted to 93 fms. A "whin float" or dolerite sill, 48 fms. in thickness, was passed through in this bore. The top of the sill lies 23 fms. below the Index Limestone, the rocks above the sill are affected by the intrusion for a vertical distance of about 8 fms.

The limestone and underlying Hirst Coals appear again at Dunns Wood, in the Castlecary ravine, where they occupy a small area on the crest of a low anticlinal fold whose axis follows the line of the glen. The section exposed at the mouth of the tunnel through which the Walton Burn is carried beneath the railway is as follows:—

	Ft.	In.
Blaes		
CALMY LIMESTONE	3	0
Blaes	6–8	0
UPPER HIRST COAL	2	2
Fireclay	4	0
Dark blaes	4	0
COAL	0	10–12
Fireclay	3	0
Sandstone		

Old crop-workings in Dunns Wood indicate that the Hirst Coal was formerly mined on the west side of the glen. The Upper and Lower (or Smithy) Hirst Coals were at one time extensively wrought in the ground to the west of the Cumbernauld road, south of Tollpark. This field is traversed by a fault with a downthrow to the north of 50–60 fms., which crosses the Castlecary ravine at Dunns Wood, and truncates the anticline in the Calmy Limestone already referred to. The Lower Hirst was also worked on the north side of this fault, beneath the Millstone Grit. Another line of dislocation, also with downthrow to north, limits the field on the south. Eastwards from the Cumbernauld road this fault appears to coincide with the east-and-west dolerite dyke which crosses the valley at the Caledonian Railway tunnel. The coals were found to be burnt in the immediate neighbourhood of this intrusion. The Netherwood workings in the Hirst Coals extended across the valley beneath the Canal as far as Auchinloch, and the Calmy Limestone and Hirst Coal are said to have been worked from a mine S.E. of Kelvinhead.

The following is the section of the Calmy Limestone, Hirst Coals, and accompanying metals in the Netherwood Pit, a short distance beyond the western margin of Stirling, 29 S.E.

		Ft.	In.
CALMY LIMESTONE	LIMESTONE	2	0
	Blaes	2	6
	LIMESTONE	1	5
	Parting	0	2
	LIMESTONE	1	6
	Blaes	5	11
	Fakes	2	9
UPPER HIRST OR SHIRVA	COAL	3	9
	Fakes	0	5
	Sandstone	3	9
	Fakes and blaes	1	6
	Blaes	2	0
	Fakes and blaes	2	6
	COAL	1	0
	Fakes	5	7
LOWER HIRST OR SMITHY	COAL	1	6½

In the shaft at Tollpark the Upper Hirst was 20 fms. from the surface. The beds are lying in a shallow basin, but to the east of the Cumbernauld road this is succeeded by a gentle anticline whose axis follows the line of the Castlecary glen, beyond which the beds dip east and south-east beneath the Millstone Grit.

The higher part of the stratigraphical sequence between the Calmy and Castlecary Limestones is fairly well exposed along the Caledonian Railway in Glenvault, north of Cumbernauld Station, where it consists chiefly of sandstones, fakes and fireclays. Half a mile south-east of Cumbernauld House the outcrops of a thin coal and a hard, grey, yellow-weathering, lenticular limestone can be followed for some distance on either side of the glen. The railway cutting at the signal post affords the following section:—

	Ft.	In.
Thick-bedded sandstone		
Dark blaes		
COAL	0	8–10
Fireclay	2	6
Sandstones, fakes and faky sandstones	35	0
Dark faky blaes	2–3	0
Grey LIMESTONE, lenticular	9 in. to 2	0
White sandy fireclay	2	0
White faky sandstone		

The coal appears to have been worked in past times from mines along the crop.

A similar lenticular limestone, 0 to 2 ft. in thickness, and probably on the same horizon, is seen further to the south in the old freestone quarry east of the road, above Glencryan Burn, where it is associated with fireclays and thick sandstones. The latter were at one time quarried for building-stone.

The dark blaes, fakes and sandstones exposed along the course of the Luggie Water, above and below the Tannoch Chemical Works, lie near the top of the Carboniferous Limestone Series, but the exact position of the upper limit of the Group in this section cannot be determined. The variability of the Castlecary Limestone in character and thickness is well illustrated in this district. In the Netherwood

Quarry, where the limestone is exposed along the top of the eastern face of the higher opening, the following sequence is displayed:—

Hard grey encrinital LIMESTONE—CASTLECARY	15–18 in.
Dark blaes with thin coal (6 in.)	5–6 ft.
Very hard ganister	6 ft.
Rooty fireclay	4–6 ft.
Thick yellow sandstone	30 ft.+

The limestone is 3 to 4 ft. thick in the bores put down between Netherwood Farmhouse and the Canal, and at the Castlecary Fireclay Works, half a mile to the east, the thickness of the seam has further increased to 6–7 ft. The seam averages as follows:—

	Ft.	In.
Sandstone		
Blaes	2	0
LIMESTONE	4	0
Blaes	0	2
LIMESTONE	2	0
COAL	0	2
Sandstone		

The upper portion, up to 18 in., of the limestone is sometimes hard and black, and of little value; it is called locally the "bonnet." The limestone is raised here for building and agricultural purposes, and has also been used as a flux in iron smelting furnaces.

Analysis of Limestone from the Castlecary Fireclay Company's Works, Castlecary, Stirlingshire.

(Sample No. 4, V. 1445.)		Per cent.
Silica	SiO_2	4·53
Titanic oxide	TiO_2	traces
Alumina	Al_2O_3	1·74
Ferric oxide	Fe_2O_3	1·35
Iron pyrites	FeS_2	·71
Nickel oxide	NiO	·01
Manganous oxide	MnO	·10
Calcium oxide	CaO	48·96
Barium oxide	BaO	·03
Magnesium oxide	MgO	1·60
Potash	K_2O	·13
Soda	Na_2O	·02
Lithia	Li_2O	nil
Carbon dioxide	CO_2	40·35
Water at 105° C.	H_2O	·88
Water above 105° C.	H_2O	·18
Phosphoric oxide	P_2O_5	traces
Sulphuric anhydride	SO_3	traces
Chlorine	Cl	traces
		100·59
Cementation Index		0·30

Ferrous oxide (FeO) was determined directly and was found to amount to 0·97 per cent., but as it is impossible, in the presence of a sulphide, to be sure that this value is correct, the whole of the iron has been calculated as ferric oxide and iron pyrites. The carbon dioxide present is no more than sufficient to combine with the lime and magnesia.

The Castlecary Limestone preserves the same thickness for some distance to the east of the Red Burn glen; at Stein's fireclay pit it reaches 6 ft., and in a bore close to the railway, south-west of Woodend, measured 7 ft., at a depth of 66 fms. from surface. It has also been wrought from a number of mines and shallow pits along the outcrop on both sides of the Castlecary glen, north of the Dunns Wood fault.

Owing to the low angle of dip and the form of the ground, a considerable surface-area within the policies of Cumbernauld House is occupied by the Castlecary Limestone, and the rock has been extensively worked here in past times both by mines and open-cast quarries. Over a small part of this area the limestone has a thin covering of sandstone and fakes belonging to the overlying Millstone Grit.

The position of this limestone to the east of Abronhill is proved in several bores between that place and the Walton Burn, at a depth of 8 to 18 fms. The calcareous shales with large concretionary limestone nodules, and limestone bands with the large encrinites characteristic of this horizon, seen in the Walton Burn at Kilt, appear to represent the outcrop of the seam. The beds along the burn are flat or rolling at low angles.

The position of the outcrop to the south of Glenvault is indicated by an old quarry, now grassed over, near Mid Forest.

In the Glencryan Mine section, a rough ferruginous limestone, 7 inches in thickness, about 45 ft. below the "cement," must be regarded as representing the Castlecary Limestone. A similar bed occurs at the same position in a tributary of the Shank Burn at Limekilns: also at Greenfoot, near Glenboig, and in bores in the Garnkirk basin. L. W. H.

Kinneil Area.

On the east side of the basin a small patch of Upper Limestone strata falls within the limits of Area II. near North Hainings, at the southern margin of the Carse of Kinneil. The Castlecary Limestone was at one time extensively worked at Craigenbuck, 300 yds. S.S.W. of North Hainings farmhouse, and also further to the south, a little to the east of the railway viaduct crossing the river Avon. At the last named locality the section is as follows:—

	Ft.	In.
LIMESTONE, grey crystalline	4	4
Blaes	0	6
LIMESTONE, concretionary	1	1
LIMESTONE, compact blue	1	1
Blaes, blue and dark grey	6	0
Faky sandstone and dark blaes . . .	4	0

The limestone is exposed in the railway cutting a quarter of a mile S.E. of North Hainings, dipping north: it is a yellowish-grey dolomitic limestone with a specific gravity of 2·86. The workings near the Avon viaduct extended 600 yds. N.E. from the outcrop, and the limestone probably continues considerably further in that direction before bending north-west round the fold at Upper Kinneil.

The limestone was mined up to about the year 1876, and was sent to the Kinneil blast furnaces.

North Hainings Bore.—A deep bore was put down in 1902–4 near North Hainings with the hope of proving the Bo'ness Coals in good condition on the western side of the Kinneil workings, but the results were not encouraging. The Calmy Limestone, in three leaves with blaes partings, was passed through at 50 fms., the Orchard, 1 ft. 10 in. at 82 fms., and the Index, 7 ft., at 145 fms. The position of the Seven-foot Coal was recognised at a depth of 32 fms. below the Index, but below this point the bore passed through an abnormally large proportion of whinstone and volcanic ash. The characteristic roof of the Smithy Coal was not recognised, but it seems certain that the whole of the rocks representing the position of the Bo'ness Coals was pierced.* The total depth of the bore was 425 fms.

Through the courtesy of Messrs. W. Baird & Co., of Bothwell Collieries, we are able to give a simplified graphic section of the North Hainings bore (see Plates VII., VIII., IX.).

Most of the "whins" indicated in this section are believed to be contemporaneous lava flows similar to those exposed near Bo'ness. These flows differ essentially from intrusive whinstone either in the form of "floats" (sills) or "gaws" (dykes) in that they rarely produce much burning or deterioration in quality of the adjacent coals. It is probable that a few of the "whins" in the North Hainings bore are intrusive in nature, but the general deterioration in value of the Limestone Coals passed through in the bore is to be attributed, not to the "burning" of existing coals, but to the original absence of good coals owing to adverse conditions for their formation.

C. T. C.

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* See also "The Geology of the neighbourhood of Edinburgh," *Mem. Geol. Survey*, 1910, pp. 136, 142.

CHAPTER III.

MILLSTONE GRIT.

Castlecary, Cumbernauld and Bonnybridge.

(Stirling, 29 N.E., S.E.; 30 N.W., S.W.; 34 N.E.)

THE thickness of this series in the districts under consideration is considerably greater than in the Glenboig and Glasgow areas to the south and south-west. At Rashiehill, a mile west of Slamannan, the thickness of the Millstone Grit, beneath the Coal Measures, is approximately 516 ft.; at South Drum, Bonnybridge, it reaches a figure approximating to 740 ft. as compared with 267 ft. in the deep bore at Gartsherrie, Coatbridge. The increase in thickness seems to be confined to the higher part of the sequence, the relative positions of the horizons from the Lower Fireclay downwards remaining very constant along the outcrop from south to north between Garnkirk and Castlecary.

Good natural sections of the Lower Fireclay and Cement Limestone horizon are exposed on the Luggie Water, immediately below the bridge on the road from Greengairs to Cumbernauld. At Rumblybugs, 300 yds. W.S.W. of Torbrex, the sequence is as below:—

		Ft.	In.
	Sandstone		
LOWER.	White FIRECLAY	4–5	0
	Friable gritty sandstone	10–15	0
	Grey FIRECLAY, white streak, shaly at base, variable in thickness	0–5	0
CEMENT.	Dark shelly LIMESTONE with *Orthotetes*	0	12–14
	Dark blaes with 2 in. COAL	1	6
	Fireclay, inferior, shaly at base	5	0
	Faky sandstone	6	0
	Soft friable sandstone		
	Dark blaes with ironstone ribs and nodules		

The white fireclay is also seen at the crop at Wester Glentore. Three shallow bores put down for water immediately south of Wester Burntrig proved a good fireclay, 4 ft. to 4 ft. 6 in. thick, beneath 30 to 35 ft. of sandstone, and it is probable that a field of workable clay lies at no great distance beneath the surface in the ground between the head of the Luggie Water and the Glencryan Burn.

The Glencryan Mine has been driven more than ¾ mile northeastwards to the dip of the Lower Fireclay, and affords an admirable section of the lower part of the series.

Starting on the outcrop of the fireclay, which lies about 15 ft. above the Cement Limestone seen in the tramway cutting, 250 yds. from the mine mouth, the mine passes, at 100 yds., through a fault throwing down to the south. On the further or upthrow side of the fault the section begins a short distance below the Castlecary Limestone, the Lower Fireclay and overlying sandstone being repeated. The whole sequence, in descending order, is as follows:—

	Ft.	In.
Hard yellow sandstone (roof of mine)		
LOWER FIRECLAY (mined)	4	9 (av.)
Sandstone	9	0
Inferior fireclay	4–6	0
CEMENT LIMESTONE in two bands with blaes parting	1	6
Dark blaes	0	2
COAL	0	2
Faky fireclay	3	0
Sandstone	35	0
Dark blaes with ironstone nodules	5	6
Base of Millstone Grit.		
Rough ferruginous LIMESTONE (CASTLECARY)	0	7
Blaes	0	2
Soft sandstone with hard ribs and fireclay bands	6	0

This section compares very closely with that found at the Greenfoot Quarry, Glenboig.

At the air shaft, No. 2, 580 yds. from the mouth of the mine, the Lower Fireclay is 50 ft. below surface; the beds dip E.N.E. at about 5°.

The Glencryan clay is of excellent quality and is used for the manufacture of furnace bricks and blocks, drain pipes, ornamental tiles and other fireclay goods.

Ultimate analysis of fireclay from the Glencryan Mine; carried out by Mr. E. C. Radley.

Silica	51·30
Titanic oxide	1·45
Alumina	29·42
Ferric oxide	2·12
Manganous oxide	·15
Cobalt and Nickel oxide	not found
Barium oxide	not found
Calcium oxide	·48
Magnesia	·49
Potash	·18
Soda	·14
Lithia	trace
Water at 105° C.	3·09
Water above 105° C.	10·75
Phosphoric acid	·20
Iron Pyrites	·01
Organic matter	·06
Carbon dioxide	·25
	100·09

"Rational" analysis by Mr. Walter C. Hancock.

Clay substance	82·22
Quartz	15·54
Felspar	2·24
	100·00

3

The Lower Fireclay was worked at an earlier period from a mine near Mid Forest, 300 yds. N.E. from the line of the Glencryan Mine. The fireclay, shelly Cement Limestone and underlying thin coal are exposed in a natural section behind the farm steading at Mid Forest.

The clay has also been mined on the east side of the lower end of Glenvault, a short distance west of Low Abronhill. These workings have recently been re-opened: the seam has an average thickness of 7 ft. and is of good quality, but the strata are troubled towards the north and appear to be approaching a large fault.

Along the upper course of the Walton Burn, above Kilt Bridge, where the lower strata of the Millstone Grit Series are undulating at low angles, the beds immediately below the Lower Fireclay position are brought up on a gentle anticlinal fold at a point about 900 yds. east-north-east of Glenhead Feus.

The section exposed in the bed of the stream is—

		Ft.	In.
	Sandstone	2	0
	Nodular FIRECLAY	4–6	0
CEMENT.	Grey shelly LIMESTONE	0	10
	Dark blaes with 4 in. coal	1	0
	Grey flaky fireclay		
	Sandstone		

The Lower Fireclay position lies immediately above the higher sandstone seen in this section, and it is not unlikely that a field of this clay may be present in the ground on either side of the burn between Crowbank and Bandominie.

The centre of the shallow syncline that lies to the west of Castlecary village is occupied by the lowest beds of the Millstone Grit, beneath a thick covering of boulder clay. In the deepest part of this basin about 43 fathoms of Millstone Grit strata, including the Lower Fireclay position, are represented.

The Lower Fireclay is wrought by the Castlecary Fireclay Co. from a pit at Castlecary Station. The base of the Lower Fireclay, here known as the Main Seam, lies 25–30 ft. above the Cementstone and 9–10 fms. above the Castlecary Limestone. The Main Seam has an average thickness of 8–9 ft., but the upper surface is often much eroded, causing a constant variation in the measurement of the bed.

The section of the seam where wrought at the present time is as follows:—

	Ft.	In.
Sandstone		
Bastard fireclay	2	6
MAIN FIRECLAY	7–8	0
Rock floor		

The bastard fireclay is sometimes absent and the good clay increases to over 5 ft. in thickness. A lower seam of fireclay, lying 3 ft. above the top of the Castlecary Limestone, has recently been opened and worked on a small scale: the clay appears to be of good quality. Another seam of clay, 8 ft. in thickness, was passed through in a mine recently driven from the old limestone workings to catch the Main Seam. This clay has been analysed, and promises to yield good refractory material: it seems to be of local occurrence, and has not been met with in natural sections further to the south.

A hard, siliceous white or grey sandstone, 2 ft. in thickness, underlies the lowest seam of fireclay, and is separated from the Castlecary Limestone only by 12–18 in. of dark blaes. The silica percentage of this rock is 90–92 per cent.; it is worked as a "ganister" and used, with an admixture of fireclay sufficient to reduce the percentage of silica to 85–87½ approximately, for the manufacture of "ganister" bricks. The Castlecary Fireclay Works supply bricks and blocks for Bessemer ladle linings; Siemens-Martin regenerative gas furnaces; gas, chemical, blast and puddling furnaces; flue covers and boiler seatings; linings of oil-fuel furnaces; coke ovens and ordinary fireclay goods.

The raw material is ground, hand-moulded and fired in circular kilns.

Appended are "Rational" and ultimate analyses of the Castlecary Fireclay.

Analyses of the Lower Fireclay from the Castlecary Fireclay Company's Pit, Castlecary, Stirlingshire, made at the Government Laboratory.

"Rational" or "Proximate" Analysis of Clay dried at 105° C.

	Per cent.
Clay substance	88·00
Quartz	11·25
Felspar	·75
	100·00

Ultimate Analysis.

		Mean.
Silica	SiO_2	50·10
Titanic oxide	TiO_2	1·21
Alumina	Al_2O_3	31·16
Ferric oxide.	Fe_2O_3	1·33
Ferrous oxide	FeO	·90
Iron pyrites.	FeS_2	·02
Nickel oxide	NiO	trace
Calcium oxide	CaO	·55
Barium oxide	BaO	·02
Magnesium oxide	MgO	·67
Potassium oxide	K_2O	·74
Lithium oxide	Li_2O	·04
Phosphoric oxide	P_2O_5	trace
Sulphuric anhydride	SO_3	trace
Chlorine	Cl	trace
Carbon dioxide	CO_2	·10
Water above 105° C.	H_2O	10·81
Water up to 105° C.	H_2O	2·33
Carbon (organic)	C	·33
Hydrogen (organic)	H	·01
		100·32
Loss on ignition		13·61

Calculated from Ultimate Analysis.

	Per cent.
Clay substance	83·80
Quartz	11·72
Felspar	4·48
	100·00

The accuracy of the results as determined for clay substance and felspar by "Rational" analysis is open to considerable doubt. The matter has been discussed by H. Ries in "Clays" (New York, 1906) p. 66, etc., and at some length by Dr. J. W. Mellor in "Quantitative Inorganic Analysis" (Griffin), p. 657, etc.

Comparison between the results of the "Rational" analysis and those calculated from the ultimate analysis shows that the felspar found in the "Rational" analysis is, in the samples referred to in this chapter, much lower than that calculated on the assumption that all the sodium and potassium oxide is present as felspar. The values for quartz are much closer. The "Rational" analysis is of considerable value for determining the proportion of quartz, but of doubtful value for ascertaining the clay substance and felspar in different kinds of clays.

An excellent section of the beds from the base of the Series up to the Lower Fireclay seam above the Cementstone is exposed in various openings and old crop workings on the west side of the Castlecary glen, about ¼ mile south of the village. The dark blaes that overlie the Castlecary Limestone, here about 18 inches thick, are succeeded by the "ganister" described above, followed by alternations of sandstones, fireclays and blaes with ironstone ribs up to the Cementstone position, which is well seen in a small quarry halfway up the bank. It is here represented by a 14-inch shelly limestone with *Orthotetid* shells. Immediately beneath the limestone is a thin coal, and above it a bed of nodular ironstone, the "Curdly Ironstone" of the Fauldhouse district, succeeded upwards by fireclay, fakes and a thick sandstone.

On the further side of the low anticline whose axis coincides with the bottom of the Castlecary glen, the strata dip steadily eastwards at low angles, and at Stein's Fireclay Works, ¾ mile east of Castlecary village, the base of the Millstone Grit lies 70 fms. and the Lower Fireclay 60 fms. below the surface. The Millstone Grit is cut off to the south by an east-and-west fault with a downthrow to the north of 50–60 fms. The position of the base of the Series in the drift-covered area on the south side of the dolerite dyke that follows the line of fault east of Walton is only approximately shown on the map; a bore put down near the farm house of Bandominie is, however, believed to have passed through the Castlecary Limestone at 25 fms., and there is good reason to suppose that the Lower Fireclay may be present at no great depth beneath the surface between Bandominie and Abronhill.

A wide tract of ground to the east, including the high moorland ground of Fannyside, is occupied by the white gritty sandstones with pebbly bands—the Moor Rock—which form the upper part of the Series. Near Glenhead, on the north side of Fannyside Muir, two thin coals appear in the sandstones; these were at one time worked from the crop: an ironstone—known as the Palacerig ironstone—and possibly on the horizon of the "Ginstane" of the Fauldhouse district, was also formerly wrought opencast 500 yds. north-west of the head of Fannyside Loch, and north of the present Labour Colony at Palacerig.

A group of fireclays and ganisters situated in the upper part of the Millstone Grit comes to the surface in the Bonnybridge district, where these rocks are of considerable value.

To these seams the name of the *Upper Fireclay* has been given to distinguish them from the similar beds of the Lower Fireclay near the base of the Series.

The outcrop of these clays can be followed south-westwards from Bonnyside to Woodend; one of the fireclays and the accompanying coal is seen at several points along the crop south of Bonnybridge reservoir and in the Skipperton burn, a quarter of a mile south of the North British Railway.

The dip of the beds is somewhat variable and at a very low angle. L. W. H.

The Upper Fireclay includes both refractory clays and ganisters. In some cases there are two or three seams of fireclay and ganister, in others a ganister separates two thick beds of fireclay: there is also generally associated with these seams a somewhat impure coal varying in thickness from a few inches to upwards of 2 feet. This coal is very possibly on the same horizon as the Bowhousebog Coal. The group is generally overlain by a massive and pure white sandstone.

The fireclays of this horizon are usually dark in colour; some of the best are, however, light grey with a tinge of lilac or reddish-brown. They are, as a rule, full of rootlets, and often contain nodules of ironstone and rounded or lenticular masses of hard siliceous sandstone.

The ganisters would be more correctly described as ganister-like sandstones: they are light-coloured, fine-grained, somewhat micaceous sandstones, fairly uniform in texture; the matrix is partly siliceous and partly argillaceous.

Specimens of ganister from Castlecary and Bonnybridge, examined under the microscope by Dr. H. Thomas, are described by him as follows:—

"All these rocks approach the English ganister very closely in some respects, more especially in the size and angularity of the quartz grains; they differ, however, in the larger proportion of mica and the greater amount of argillaceous matter in the matrix. The English ganisters have a more or less pure siliceous cement, and I should expect that these Scottish rocks have a lower silica percentage and higher alkalies and lime."

The Bonnybridge ganisters have a silica percentage of 91·73 to 95·5; alkalies vary from ·26 to ·30, and lime percentages from a trace only up to ·45.*

The Upper Fireclay has for many years been wrought from mines and shafts along the outcrop between Glenyards and Bonnyside. At the present time (1916) the fireclays and ganister are being worked by several different companies, all of whom, in addition to selling the material in the raw state, have brick-works of their own situated near the Main North British Railway line.

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* These figures are taken from analyses supplied by the Bonnybridge fireclay companies.

The Bonnyside Fireclay Works: James Dougall & Sons, Ltd.

The section of the Bonnyside workings is as follows:—

	Ft.	In.
Sandstone roof		
Top Fireclay	2	9
Coal	1	6
Brownstone rib	0	4
Coal	0	3
Top Ganister	3	0
Mid Fireclay	5	0
Bottom Ganister	3	0
Bottom Fireclay	1	8
Rock pavement		

The seams vary in thickness from point to point, the full working ranging from 13 to 22 ft. The shaft is 17 fms. in depth. The beds are wrought on the "stoop and room" system, the top clay working being kept some 9 ft. in advance. The Mid Fireclay is regarded as the best seam: it provides suitable material for patent stoppers, nozzles and other special goods.

The coal is somewhat pyritous, but is used as fuel for the boilers.

The two seams of ganister are also wrought here and supply ground ganister as well as material for ganister bricks suitable for use in furnace crowns and cupola linings.

The upper seam is dark and rooty: the lower one white with a faint yellow tinge. The top seam is considered the better of the two.[*]

At the workings of *The Bonnybridge Silica and Fireclay Company Ltd.*, the section is as follows:—

	Ft.	In.	
Sandstone roof			
Top Fireclay	5	0	First working.
Coal	1	4	
Brown rib	0	5	
Mid Fireclay	2	0	Second working.
Ganister	3	0	
Bottom Fireclay	6–8	0	

The Top Fireclay is sometimes absent, the sandstone resting directly on the coal. The seams, as usual, vary considerably in thickness: the lowest fireclay is the best and no doubt corresponds in part to the Mid Fireclay of Bonnyside. The seams were formerly raised from a 12 fms. shaft, but are now wrought from a mine.

The 3-ft. ganister is also worked. It is a light-coloured, fine-grained siliceous rock, and is chiefly sold in the ground condition: some ganister bricks are also made.

The Upper Fireclay and Ganister was formerly raised from a shallow shaft at Glenyards, a short distance south of Greenhill Junction. Owing to trouble with subsidences and water these workings were abandoned and a mine driven to catch the seam further to the east.

The average section of the seam in the old workings was as below:—

	Ft.	In.
Sandstone roof		
Sandstone and blaes	3	0
Foul Coal	up to 1	2
Fireclay	5	0
Ganister	2	0
Fireclay	5	0
Sandstone		

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[*] For analyses and physical tests of fireclay from Bonnyside Works, see p. 35.

This section is much the same as that at Bonnybridge, but the position of the top clay of that working is here occupied by sandstone and blaes.

The mine referred to above struck fireclay at a depth of 7 fms., but the seam proved to be thin and very irregular.

At the *Roughcastle Fireclay Works,* about one mile east of Bonnybridge Station, three seams of fireclay or ganister are wrought: the lowest of these lies in the Millstone Grit and occupies the same position as the Upper Fireclay of Bonnybridge.

The section shows—

	Ft.	In.
Sandstone	60–80	0
FIRECLAY	3	0
COAL	1	8
Brownstone rib	0	5
FIRECLAY	5	0

The fireclay beneath the coal is locally represented by a ganister —a somewhat friable, fine-grained micaceous sandstone, pale-grey in colour and streaked with carbonaceous matter.

The Roughcastle fireclay supplies ordinary firebricks and blocks for steel furnaces and gasworks: it has been also in large demand for stove-backs for army use during the war.

The range of fireclay goods manufactured from the Upper Fireclay of the Bonnybridge district is wide. It includes bricks and blocks for different parts of steel furnaces, gas producers, blast and puddling furnaces, coke ovens and gas works, and many other purposes.

The ground clay is also sold, both in the wet and dry state, to foundries, steel and chemical works. The ganister is also supplied in the milled condition for lining converters in steel works, etc.: at some of the works it is also made into silica bricks for furnace crowns and cupola linings. M. M.

Analyses of two samples of the Upper Fireclay from the Bonnyside Firebrick Works, Bonnybridge, made at the Government Laboratory.

"Rational" or "Proximate" Analysis of Clays dried at 105° C.

	(Sample No. 1, V. 1442). Per cent.	(Sample No. 2,* V. 1443). Per cent.
Clay substance	92·63	97·14
Quartz	7·12	2·38
Felspar	·25	·48
	100·00	100·00

Calculated from Ultimate Analysis (see below).

Clay substance	86·90	92·29
Quartz	6·60	2·60
Felspar	6·70	5·11
	100·20	100·00

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* This sample contained about 5 per cent. of stones, which were removed before analysis.

Ultimate Analysis, Upper Fireclay, Bonnyside Firebrick Works, Bonnybridge.

		Sample No. 1, V. 1442.	Sample No. 2, V. 1443.
Silica . .	SiO_2	47·95	45·07
Titanic oxide .	TiO_2	1·51	1·12
Alumina . .	Al_2O_3	32 74	34·22
Ferric oxide .	Fe_2O_3	1·22	·99
Ferrous oxide .	FeO	·75	1·85
Iron pyrites . .	FeS_2	·04	·06
Manganous oxide .	MnO	·01	·03
Calcium oxide .	CaO	·28	·24
Barium oxide .	BaO	trace	trace
Magnesium oxide .	MgO	·61	·63
Potassium oxide .	K_2O	·97	·83
Sodium oxide .	Na_2O	·10	·01
Lithium oxide .	Li_2O	·03	·03
Sulphuric anhydride	SO_3	·01	·01
Chlorine . .	Cl	·02	·02
Carbon dioxide .	CO_2	·32	·88
Water above 105° C.	H_2O	11·38	11·72
Water at 105° C .	H_2O	1·83	2·00
Carbon (organic)	C	·57	·59
Hydrogen (organic) .	H	·04	·04
		100·38	100·34
Loss on ignition . .		14·02	15·04

Physical Tests of Fireclays from Castlecary and Bonnyside.

	Upper Fireclay, Bonnyside.		Lower Fireclay, Castlecary.
	Sample 1, V. 1442.	Sample 2, V. 1443.	Sample 3, V. 1444.
TESTS ON UNBURNT MATERIAL—			
Specific gravity at 15·5° C. . .	2·564	2·564	2·548
Plasticity number . . .	15·6	12·1	14·0
Shrinkage on air-drying . .	3·0%	3·0%	2·0%
Tensile strength—lbs. per sq. inch	48·6	13·6	38·6
Texture :—Clay substance . .	16·77%	6·79%	14·66%
(aver. diam. mms.) .	(·0178)	(·0096)	(·0126)
Silt	7·50%	11·35%	1·09%
(aver. diam. mms.) .	(·0290)	(·0163)	(·0201)
Dust sand . . .	1·71%	0·58%	9·08%
(aver. diam. mms.) .	(·0408)	(·0429)	(·0384)
Sand	73·67%	80·36%	74·48%
(aver. diam. mms.) .	(·413)	(·200)	(·266)
TESTS ON BURNT MATERIAL—			
Specific gravity, at 15·5° C., of material burnt to 1200° C. .	2·694	2·722	2·673
Shrinkage at 500° C. . . .	4·0%	3·0%	2·0%
,, ,, 800° C. . . .	5·0%	5·0%	4·0%
,, ,, 1000° C. . . .	5·4%	5·0%	4·8%
,, ,, 1200° C. . . .	8·0%	7·2%	6·6%
Porosity after burning to 1200° C.	5·50%	5·59%	6·65%
Fusing point . . .	Above cone 30 Above 1730° C.	Above cone 30 Above 1730° C.	Above cone 30 Above 1730° C.

The texture was determined by "Schoene's Method" as described in Ries' "Clays," p. 138.

The actual dimensions of the particles as measured are shown in the table.

The *fusion point* was determined by the use of Seger's cones; the temperature of fusion as determined from the cone is also given in the table.

According to Ries' classification, these clays are semi-refractory. The Stirlingshire clays have fusion points which are near the border line between the refractory and semi-refractory class, and they ought perhaps to be classed as refractory.

Torwood and Plean.

(Stirling, 24 N.W., S.W.).

Our knowledge of the Millstone Grit strata in the ground to the north and north-west of Larbert has also been largely increased in recent years by the information supplied from the bores of which mention has already been made in the preceding chapter (p. 5).

By the examination of the cores from these borings certain definite fossiliferous horizons have been established which have not as yet been met with elsewhere on the west side of the Lanarkshire basin. These horizons are of great use in fixing positions during boring operations, especially with regard to the valuable fireclays of this formation.

The area is for the most part deeply covered with drift, but large glaciated surfaces of sandstone are exposed in Torwood and in the plantations near Plean Mill and Carbrook House. The best continuous natural section is found in Torwood Glen. The beds dip more or less in an easterly direction at angles not exceeding 5° or 6°.

The surface position of the base of the Coal Measures northwards from Larbert can only be approximately laid down on the map; that of the Castlecary Limestone on the west side of the area can be more accurately determined. The mean breadth of the outcrop of the Millstone Grit between these two boundaries is nearly ten miles.

A powerful east-and-west fault, throwing down to the south, crosses the area north of Carbrook House, and shifts the outcrop of the base of the formation from the foot of Torwood Glen to Carbrook Mains, a distance of nearly a mile, while further to the north the outcrop is cut off by another fault which brings down the Millstone Grit against Carboniferous Limestone strata above the Calmy Limestone to the east of Plean village.

The total thickness of the Millstone Grit in the Plean area cannot be definitely ascertained in any measurable section: 113 fms. of strata belonging to this Series were passed through above the Castlecary Limestone in the Rosehill bore, but the amount of higher beds unrepresented in this section is unknown. An estimate based on the breadth of outcrop and average angle of dip gives an approximate thickness for the whole Series of 900 to 960 ft.

The excellent natural section exposed in Torwood Glen has been examined by Mr. Tait, and the fossils collected have been submitted to Dr. Wheelton Hind for determination.* The Torwood section only shows the lowest 140 ft. of the Millstone Grit, but is important since it affords good exposures of the fossiliferous horizons and the fireclays which distinguish the lower part of the sequence.

The Torwood Glen section is given in detail below.

		Ft.	In.
Fireclay		5	0
Ganister		3	0
Fireclay		3	6
Blaes		1	0
Shelly Limestone	Marine Band No. 3	1	6
Thin Coal		0	3
Fireclay		5	0
Sandstone		12	0
Blaes with fossils		1	0
Barren Limestone		1	8
Thin Coal			
Fireclay		10	0
Sandstone		6	0
Fireclay		16	6
Sandstone, clayey		12	0
Sandstone		15	6
Fireclay	Probably on the horizon of the LOWER FIRECLAY	3	0
Ganister		1	8
Fireclay		7	0
Sandstone		11	0
Shelly Limestone.	Marine Band No. 2	2	0
Sandstone		9	0
Blaes		4	6
Poor sandy Limestone	Marine Band No. 1	1	0
Bluish blaes		0	9
Coal		0	6
Fireclay		5	0
Shale		4	0
Limestone, CASTLECARY		6	0

The two bores in which the fossiliferous horizons already referred to are best shown are No. 1 Diamond Bore, Rosehill, 1 mile east of Carbrook Mains; and No. 3 Diamond Bore, Carbrook, ½ mile east by north of the farmhouse of that name (see Plate IV.).

The cores of these bores have been examined by the officers of the Survey, and the lamellibranchs and plants submitted respectively to Dr. Wheelton Hind and Dr. Kidston for determination.

In each of these bore sections and in the natural section of Torwood Glen, given above, there are present three well-marked calcareous horizons characterised by an assemblage of marine forms which do not occur higher up in the Series. These horizons are distinguished, and shown on the 6-inch map as Marine Bands, Nos. 1, 2 and 3. The second or middle of these bands has been correlated with the "Cement Limestone" of the Glenboig and Castlecary fireclay fields, and is therefore of importance as an index-mark for the position of the Lower Fireclay. In this district it underlies a constant and thick bed of fireclay, which was formerly worked at the crop in Torwood.

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* Wheelton Hind, "On the Lamellibranch and Gasteropod Fauna found in the Millstone Grit of Scotland." *Trans. Roy. Soc. Edinburgh*, vol. xlvi., 1909, p 331.

A comparison of the three sections referred to in the preceding paragraph shows slight differences in the number of fossiliferous bands at each of the marine horizons, and in the thickness of the intervening strata: these variations may be attributed to local differences in sedimentation.

The lowest or No. 1 " Marine Band " of Torwood Glen is a sandy cement limestone associated with bluish blaes and a 6-in. coal, and lies 15 ft. above the Castlecary Limestone; it contains the following fauna:—

Derbyia sp.
Lingula sp.
Ctenodonta laevirostris (*Portl.*)
Edmondia excentrica *Hind.*
E. lyelli *Hind*
E. sulcata (*Phill.*).
Limatulina alternata (*M'Coy*).
Modiola subelliptica *Meek.*
Myalina redesdalensis *Hind.*
M. verneuilli (*M'Coy*).
Nuculana attenuata (*Flem.*).
Protoschizodus curtus (*Meek and Worthen*).
P. subaequalis *de Kon.*
Sanguinolites occidentalis (*Meek and Hayden*).
Schizodus wheeleri (*Swallow*).
Tellinomorpha hindii *Bolton.*
Entalis meekianum (*Geinitz*).
Ptychomphalina marcouiana (*Geinitz*).

The corresponding horizon in the Carbrook No. 3 bore lies 3 fms. 3 ft. above the Castlecary Limestone; it consists of 8 in. of dark limy blaes and contains:—

Productus *aff.* corrugatus *M'Coy.*
Productus sp. [semireticulate].
Edmondia sulcata (*Phill.*).
Myalina verneuilli (*M'Coy*).
Nuculana attenuata (*Flem.*).
Protoschizodus curtus (*Meek and Worthen*)
Sanguinolites interruptus *Hind.*
Schizodus wheeleri (*Swallow*).
Sedgwickia sp.
Solenomya primaeva (*Phill.*).
Murchisonid.

In the Rosehill Bore, No. 1 Band, 5 fms. above the Castlecary Limestone, is a 14-in. bed of limy fakes overlain by 4½ ft. of dark fossiliferous blaes with ironstone nodules: the fossils include—

Edmondia sp.
Limatulina alternata (*M'Coy*).
Nucula aequalis *J. de C. Sow.*
N. gibbosa *Flem.*
Schizodus wheeleri (*Swallow*).
Tellinomorpha hindii *Bolton.*
Macrocheilina sp.
Naticopsis sp.

The second " Marine Band " in Torwood Glen is a shelly cement limestone, containing only rolled brachiopoda; it lies 30 ft. above the Castlecary Limestone.

In the Carbrook Bore it forms two bands of limy blaes, 8 fms. and 8 fms. 4 ft. above the Castlecary Limestone, and contains—

Lingula mytiloides *J. Sow.*
Productus sp. [semireticulate].
Schizodus wheeleri (*Swallow*).
Euphemus sp.
Naticopsis brevispira (*de Ryckholt*).
? Murchisonid.
Orthoceras sp.

In the Rosehill Bore it is a 9-in. bed of shelly limestone, 10 fms. above the Castlecary, with—

Derbyia sp.
Lingula mytiloides *J. Sow.*
Orthid.
Productus sp.
Nucula aequalis *J. de C. Sow.*
N. gibbosa *Flem.*
Schizodus wheeleri (*Swallow*).

The third or highest "Marine Band" in the Torwood section consists of two bands of cement limestone with blaes above, separated by 17 ft. of fireclay and sandstone. The upper limestone is shelly; in the lower bed the fossils are contained in the overlying blaes; they are as follows:—

Derbyia sp.
Lingula sp.
Productus sp.
Schizodus wheeleri (*Swallow*).
Bellerophon sp.

In the Carbrook Bore this horizon occurs as three thin bands of limy blaes, 34–35 fms. above the Castlecary Limestone.

Fossil contents—

Chonetes sp.
Lingula mytiloides *J. Sow.*
Productus longispinus *J. Sow.*
Productus sp. [semireticulate].
Rhipidomella michelini (*L'Eveillé*).
Schizophoria resupinata (*Martin*).
Edmondia nebrascensis (*Geinitz*).
Modiola subelliptica *Meek.*
Euphemus sp.
Murchisonid.
Naticopsis brevispira (*de Ryckholt*).

In the Rosehill Bore there are also three fossiliferous bands at this horizon within a vertical distance of 2 fms. 5 ft., the lowest being 38 fms. above the Castlecary Limestone. They contain the following forms:—

Rossophyllum novum *Stuck.*
Derbyia sp.
Lingula mytiloides *J. Sow.*
Productus sp.
Schizophoria resupinata (*Mart.*).
Edmondia nebrascensis (*Geinitz*).
Sanguinolites occidentalis (*Meek and Hayden*).
Entalis ornata *de Kon.*
Euphemus urei (*Flem.*).
Macrocheilina rectilinea (*Phill.*).
Murchisonid.
Orthoceras.

These fossiliferous horizons have also been recorded in some of the older bores put down on the estate of Torwood and Dunipace.

Sphenopteris obtusiloba Brongt, a characteristic Upper Carboniferous plant, has been identified by Dr. Kidston from the Rosehill Bore; it occurs at two horizons, 54 fms. and 57 fms. 3 ft. from surface, or, in the latter case, 63 fms. above the base of the Millstone Grit. About the same position, from 50 to 58 fms. from surface, the following forms were obtained in the same bore, *Lingula mytiloides*, *L. squamiformis*, *Orbiculoidea nitida*, *Productus sp.*, *Serpula* and *Conularia*. It is noteworthy that the fossils seem to be confined to these species and that none of the lamellibranchs characteristic of the three "Marine Bands" below are present.

The higher parts of the sequence passed through in the Rosehill bore consist chiefly of fine-grained quartzose sandstones and coarse, gritty, felspathic sandstones, with subsidiary bands of thin, coaly blaes and thicker fireclays. As already stated, the highest beds of the Millstone Grit Series do not appear within any of the known sections in the Plean district, nor have the upper fireclays and ganisters of Bonnybridge yet been identified in this area.

C. B. C.

Inveravon District.

(Linlithgow, 1 N.W., S.W.)

This district includes the course of the River Avon between Jinkabout Mill and Tod's Mill, and also the small part of Area II. that lies north-east of the river. Excepting for small cuttings on the railway and the section along the stream ⅓ mile E.S.E. of Inveravon, the only exposures are those along the Avon. Unfortunately these are not continuous and are crossed by faults, the effects of which are not quite clear. It seems probable that the beds vary rapidly in development from place to place. Instead of attempting a general section we give, on Plate III., three short sections of different localities—(1) the east side of the railway viaduct; (2) the north-east side of the Avon, 100 yds. below Tod's Mill; and (3) the Avon Valley just east of the viaduct. Section 1 and most of Section 3 lie a little beyond the limits of Area II.

The bituminous shale is seen just above the Castlecary Limestone on the north side of the river, 120 yds. above the viaduct. The thickness in this exposure is 2½ ft., but in the old limestone working it was in some places a foot more (see p. 26). The journal of the bore in the Willow Bog, on the north side of the river, 400 or 500 ft. south of Inveravon, makes no mention of the shale, though a limestone was pierced which is believed to be the Castlecary. The bituminous shale in the Avon is certainly in the position of the Levenseat Shale, which was formerly worked on the east side of Levenseat as an oil producer. A sample of the Levenseat Shale, tested at Broxburn, gave per ton 34·3 gallons of crude oil of sp. gr. 90·4, and 4·3 lbs. of sulphate of ammonia (lab. tube).*

The three bands of ironstone or ferruginous limestone that lie between 4 and 12 fms. above the base of Section 1 are no doubt either in or near the position of the Cement Limestone of Lanarkshire and of the Curdly Ironstone which in most districts is found just above that limestone. The 4-ft. impure ferruginous limestone or blaes at 21 fms. 5 ft. 6 in. has yielded remains of the peculiar lamellibranchs which were first described from the Coal Measures of Nebraska, but have now been identified by Dr. Wheelton Hind from a considerable number of Scottish localities.*

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* "Oil Shales of the Lothians" (*Mem. Geol. Survey*), 1912, p. 146. The analysis of a sample of crude oil got from the same shale is given on p. 155 of the same memoir.

The 8- to 10-in. coal near the middle of Section 1 was formerly visible at the north side of the river, 80 yds. below the viaduct, and has been worked also on the same side of the river a little lower down on the upthrow side of a small fault.

The thick fireclay at 11 fms. 4 ft. in Section 1 has been mined by a day level on the north side of the river just east of the viaduct. It is believed to be of good quality, and must be in much the same geological position as the Lower Fireclay of Glenboig.

In Section 2 the clay-shale with marine shells, at 8 fms. 1 ft. and the shelly ironstone just below, both contain remains of the peculiar molluscan fauna already referred to, but they are apparently a somewhat higher horizon than the beds which yielded the similar remains in Section 1. Several old adits have been driven a short distance into the river cliff about 100 yds. below Tod's Mill, presumably for the purpose of winning the clay-shale and fireclay below.

Section 3, taken from the railway cutting, includes beds that are also seen on the south-west side of the Avon close to Tod's Mill. The 7-fm. fireclay at 11½ fms. varies rather rapidly in character. In one place it showed the following subdivisions:—

	Fms.	Ft.	In.
DARK GREY FIRECLAY	1	2	0
PALE AND DARK GREY FIRECLAY	2	3	0
PURPLE AND RED FIRECLAY	0	4	0
FIRECLAY WITH IRONSTONE NODULES	0	5	0
PALE FIRECLAY	0	5	0
FIRECLAY AND GANISTER	0	5	0

Fireclay belonging to this 7-fm. bed was formerly worked near the crop just south-west of the railway cutting, where it certainly overlies the beds of Section 2. More recently Messrs. P. & M. Hurll have tested various samples of the fireclay in the cutting, and are preparing to work the clay again. Mr. M. Hurll states that the dark grey clay at the top gives the palest and best bricks. He believes that the 7-fm. fireclay in the cutting is the same as the thick clay in Section 1. This it may be, for an east-and-west fault that crosses the Avon near Tod's Mill has certainly a downthrow to the south, though it is difficult to fix its exact amount. On the other hand, there is no very close resemblance between the beds in Section 3 and those which, on the supposition referred to, should correspond with them in Section 1. If the lower strata in Section 3 are not also the top beds of Section 1, the latter must be below the former, the fault between them being perhaps of but small amount.

The 7-fm. fireclay of the cutting can be traced north-west until it comes down to the river side at a point about 1400 ft. north of Tod's Mill.

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* "On the Lamellibranch and Gasteropod Fauna found in the Millstone Grit of Scotland," *Trans. Roy. Soc., Edin.*, vol. xlvi., 1909, p. 331.

The 16-in. coal is seen on the north-east side of the railway line about 1900 ft. N.N.E. of the viaduct. No seam that appears to correspond to this is recorded in the journal of a recent bore put down about 700 ft. east of the exposure. A 6-in. splint coal into which two small trial holes have been made in the small burn about ⅓ mile E.S.E. of Inveravon may possibly represent the 16-in. seam, but this is uncertain. A little below the splint coal a 1-ft. shelly ironstone is seen about 120 yds. below the trial holes. No such ironstone is exposed in the railway cutting, but it may be hidden in an obscured space. Beds of sandstone which must lie above the splint coal are seen in the Avon a little below the foot of the small burn alluded to.

The journal of a bore, said to have been put down about 3000 ft. N.N.E. of the viaduct, does not inspire confidence. The depth is given as 50 fms., and no limestone is recorded save near the top, at about 7 fms. A 9-in coal at 9 fms. may perhaps represent the 16-inch seam. C. T. C.

CHAPTER IV.

COAL MEASURES.

The Banknock Coalfield.

(Stirling, 29 N.W., N.E.; 30 N.W.)

General Description.—The Banknock field lies on the north side of the Forth and Clyde Canal, between Banton and Bonnybridge, and forms an outlying strip of Coal Measures, let down by two roughly parallel east-and-west faults in a deep trough between the Carboniferous Limestone on the north and the Millstone Grit on the south.

The Coal Measure strata in this outlier are arranged in three distinct basins, separated by narrow anticlinal ridges; the longer axes of the folds have a general N.E. to N.N.E. trend, and all these structures are truncated by the parallel faults which bound the area. The axes of folding thus agree in general direction with that of the well-known anticline of the "Riggin" at Kilsyth, and are in conformity with the general system of folding of the Central Valley.

The field has been worked in three separate sections, dependent to some extent on the structure of the ground: these are known respectively, from west to east, as the Coneypark, Banknock and Dennyloanhead workings.

Mining operations at Coneypark have been confined to the deeper parts of the most westerly of these three basins, and lie on the downthrow side of a fault which crosses the basin and separates the Coneypark workings from those of Banknock. The latter chiefly occupy the shallower eastern part of the syncline, the seven upper seams of the Coneypark sequence being here absent. The Dennyloanhead workings include the Broomrigg and Bonnyrigg basins in the eastern half of the outlier.

The accompanying horizontal section (Fig. 3) is drawn from west to east along the Coal Measure outlier and illustrates the general structure described above. It also shows the greater steepness and consequent depth of the beds on the western or Coneypark side of the Coneypark-Banknock basin. The names of the coal seams corresponding to the numbers given on the section will be found in the table, page 47.

Along the south side of the outlier the Coal Measures are thrown against Millstone Grit. The northern boundary fault is of much greater dimensions, the Coal Measures being let down against strata ranging in position from above the Calmy Limestone in the east to the Kilsyth Coking Coal in the west, the throw in the latter case amounting to more than 500 fms. This dislocation joins the great Campsie fault* N.N.E. of Kilsyth, and extends eastwards to the sea at Grangemouth, a distance of more than 14 miles.

A number of smaller faults branch off obliquely from the boundary faults but usually die out without crossing the field. The direction of throw of these minor dislocations is generally the same as that of the line of disturbance from which they diverge, and the amount of throw lessens gradually from their point of origin to their termination. An exception is found in the curved fault to the north of the Knowehead workings; this makes a sharp convex bend towards the north, and at each extremity approaches, and probably joins, the southern boundary fault. Its throw is, however, down to the south.

The amount of throw of the faults varies considerably from point to point; this variation is due not only to the reasons given above but also to the folding of the strata. The general dip of the rocks outside the trough-fault-block being to the east, the throw of the boundary faults is greatest at the west end of the field, since the highest horizons in the Coal Measures are met with at either extremity of the outlier.

In spite of its small size and isolated position the Banknock field includes nearly the whole sequence of the Productive Coal Measures of the Lanarkshire basin. The highest seam wrought occupies about the position of the Ell Coal of Lanarkshire, the lowest lies on the horizon of the Mill or Auchingane Coal of the Falkirk area. Between these positions 15 coal seams are known, and have at one time or other been wrought, while still lower coals have been met with in bores.

It is doubtful whether any of the Barren Red Measures are represented in the area; indeed the apparent thickness of strata above the highest coal does not admit the presence of the base of the

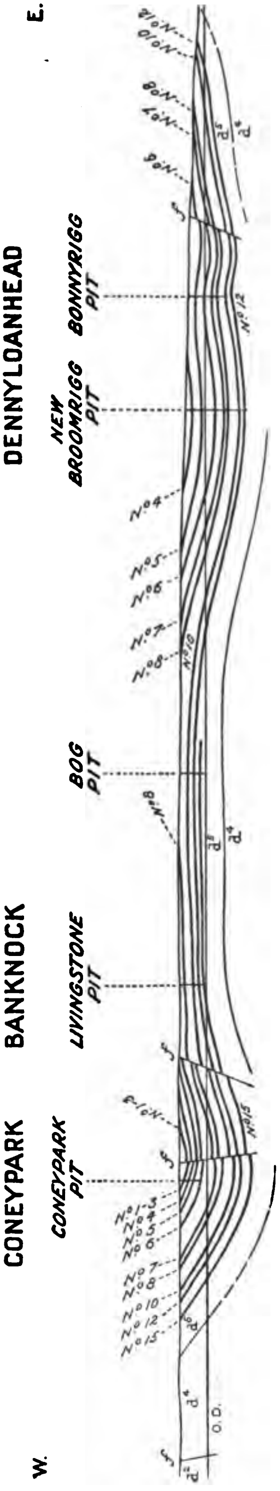

Fig. 3.—Section from west to east along the Banknock Coal Measure Outlier.

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* See "The Geology of the Glasgow District," *Mem. Geol. Survey*, 1911, p. 166.

upper measures, which in the Coatbridge district is drawn 53 fms. above the Upper Coal of Lanarkshire.

The coal seams of the Banknock fields have acquired local names from their correlation—in most cases probably correct—with the seams of the Lanarkshire basin. Unfortunately different names have sometimes been given to the same coal in different parts of the area. Thus the Virtuewell of Dennyloanhead was worked at Coneypark under the name of the Lady Ha', while the Lower Drumgray of Coneypark is the Jewel of Banknock and the Mid Drumgray of Dennyloanhead. The name of "Jewel" is also sometimes given to the Ladygrange coal of the Dennyloanhead field.

To avoid this confusion in nomenclature, the Banknock Coal Company has adopted the system of numbering the seams downwards from No. 1 to No. 17, beginning with the highest worked coal—the Thick Coal of Coneypark.

A seam 3 ft. in thickness is reported to have been met with near the top of the Coneypark section and about 24 fms. above the Thick Coal of Coneypark—No. 1: this may possibly represent the Upper Coal of Lanarkshire. The highest seams, Nos. 1–3 (see Table, p. 47), worked in this area seem to lie between the horizons of the Ell and Pyotshaw and Main Coals of the Lanarkshire sequence.

The strata immediately above and below the Musselband Coal (No. 6) are usually red in colour and consist of red sandstones and marls and blaes with ironstones. There are usually two ironstone horizons between Nos. 5 and No. 7; each of these ironstones is locally a "musselband."

The coals numbered 7 and 8 are generally separated by a considerable thickness of metals from the seams above and below them, and the red strata so constantly met with throughout the field in this barren part of the sequence may indicate a change in the conditions of sedimentation. No. 9—the Shale Coal—is always accompanied by a musselband and oil-shale; it thus forms a constant index horizon, and may confidently be correlated with the Kiltongue Musselband of Lanarkshire and with the Miller or Two-Foot-Coal of the district further to the east. This is succeeded by the Main Coal of Banknock—No. 10—the equivalent of the Kiltongue of the west, and called by that name both at Coneypark and Dennyloanhead. At the latter locality the Kiltongue is split into two seams, the lower part going by the name of the Lower Splint or Blackband (No. 11). These two coals are represented in the Carron field by the two leaves of the Crow Coal. The next named seam, No. 12, is always associated with a musselband, and is regarded as the equivalent of the Main Coal of Carron and the Upper Drumgray of Lanarkshire, both of which are similarly distinguished by an overlying musselband.

The three next seams below No. 12, as will be seen in the table below, are differently named in the three workings of the Banknock coalfield. No. 13, the Lower Drumgray of Coneypark, is the Jewel of Banknock and the Mid Drumgray of Dennyloanhead; it is also considered to represent the Mid Splint of the Carron field: No. 14, the Coxrod of Coneypark, is known as the Upper Drumgray or Dirt

Coal at Banknock: No. 15, the Lower Drumgray of Banknock and Dennyloanhead, is the equivalent of the Lower Coxrod of the other coalfields of Stirlingshire. These three seams have a constant relation to one another; the highest, No. 13, lies some distance above the other two, which are always close together and often only separated by a fireclay.

A coal lying at an average depth of 10 fms. below the Lower Drumgray (No. 15) is the lowest seam worked at Banknock, where it is called the Third Drumgray. It possibly represents the Mill Coal of the Carron and Falkirk fields, but appears to be without the characteristic parrot coal.

The lower group of coals of the Falkirk coalfields, from the Glenfuir or Armadale Main to the Lower Slatyband Ironstone position, do not attain a workable thickness in the Banknock outlier.

The officials of the Company have given valuable assistance in drawing up the following table, which gives the numbers of the seams, the local names used in different parts of the field, and, where fairly certain, their equivalents in other parts of Stirlingshire and in Lanarkshire.

No.	Coneypark.	Banknock.	Dennyloanhead.	Other Coalfields of East Stirlingshire.	Lanarkshire.
1.	Thick coal	...	Ell.	...	...
2.	...	...	Soft.	...	...
3.	Main	...	Splint.	...	...
4.	Humph Steel	...	Hard or Main.	...	...
5.	Splint Virgin	...	Humph or Splint. Splint or Virgin.	... ...	... ...
6.	Musselband	...	Thin coal and Musselband.	...	...
7.	Lady Ha'	...	Virtuewell.	Wee or Virtuewell	Virtuewell. (?)
8.	Virtuewell or Fivequarter	Virtuewell or Fivequarter	Ladygrange	Diamond or Ladygrange	Ladygrange. (?)
9.	Shale	Shale or Musselband	Shale	Miller or Two Foot	Kiltongue Musselband.
10.	Kiltongue	Main	Kiltongue	Craw or Crow	Kiltongue.
11.	Thin coal	Ell or Pavement	Lower Splint or Blackband.	...	...
12.	Upper Drumgray	Splint	Upper Drumgray	Splint or Carron Main	Upper Drumgray.
13.	Lower Drumgray	Banknock Jewel	Mid Drumgray.	Mid Splint of Carron	...
14.	Coxrod.	Upper Drumgray	Thin coal	Coxrod or Upper Coxrod	Lower Drumgray.
15.	...	Lower Drumgray	Lower Drumgray	Lower Coxrod.	...
16.	...	Soft.	...	...	...
17.	...	Third Drumgray or Ball	Ball	Mill. (?)	...

C. B. C., L. W. H.

The lowest seam (No. 17) is more probably equivalent to the Mill Coal than to the Ball Coal of Linlithgowshire. The association of persistent musselbands with Nos. 12 and 9 make their correlation with coals in outside areas almost a certainty. As regards Nos. 8 and 7, all that can be said is that they—and their East Stirlingshire equivalents—may be both approximately on the horizon of the

Virtuewell of Lanarkshire. Between Nos. 5 and 7 is a fairly wide interval, characterized by musselbands and one relatively unimportant coal. This may represent the similarly barren interval between the Virtuewell and Virgin coals of Lanarkshire; it is thus possible that the seams included under No. 5 may be the true equivalents of the Humph-Splint-Virgin group of the west. As to the correlation of the higher seams we are not at present in a position to hazard any definite opinion. E. M. A.

A more detailed account of the different workings in the area will now be given.

Coneypark.

The coals of this field occupy a deep basin whose centre lies a little to the north of Coneypark farmhouse. An old pit was sunk at that spot to the Kiltongue Coal which lay at a depth variously stated as 98 or 110 fms. from surface.

At least three sections of this old shaft are in existence, but the details of the sequence between No. 6 and No. 9 coals vary, and the figures are consequently unreliable. The section given below has been drawn up from these shaft sections in conjunction with the bore put down in 1888 in the Coneypark Plantation, which passed through all the strata between the Coneypark Thick Coal (No. 1) and the Musselband Coal (No. 6). To this was added the information derived from a cross-cut mine driven from the Virtuewell (8) to the Splint (5) immediately north of the railway, and about 600 ft. west of Banknock Station. The measurements taken across the dip in this mine of the distances between No. 6 and No. 9 coals are considerably less than those given in the old shaft sections, and more in accordance with the section between these horizons in the Dennyloanhead area.

In addition to the old shaft at Coneypark Farm, the following shafts and mines have been employed in working the coals.

1. *Stackyard Pit.*—250 yds. north of Coneypark House; 25 fms. to No. 8 coal (Virtuewell).
2. *Pumping Pit.*—Beside the railway line, 300 yds. north-east of the last named; 67 fms. to No. 10 (Kiltongue).
3. *West Pit.*—Beside the railway line, 600 feet N.W. of Coneypark House; 22 fms. to No. 9 (the Shale Coal) and sunk to No. 12 (Upper Drumgray).

These three pits were all connected with workings in No. 9 coal, the seam which has been most extensively wrought at Coneypark.

Another pit, sunk 37 fms. to the Virtuewell Coal, 800 ft. east of the Pumping Pit, is in communication with a day level emerging near the Bankier distillery. The Virtuewell and Kiltongue were also wrought from the West Pit, and the Shale Coal by a cross-cut mine 300 ft. further to the west: the Drumgray and Coxrod seams have been formerly worked over small areas from two mines near Jewelbank Cottage.

The following table shows the stratigraphical sequence at Coneypark: the local names and numbers are appended to the different coal seams.

		Fms.	Ft.	In.
	Strata—said to be chiefly red sandstone	6	0	0
	Coal—possibly representing the Upper Coal of Lanarkshire	0	3	0
	Strata . . . . . . about	22	0	0
Nos. 1–3.	Coal—Coneypark Thick Coal or Pyotshaw	0	5	4
	Strata—sandy fireclay	0	3	0
	Coal—Coneypark Main	0	3	3
	Strata—fakes and blaes with ironstone ribs	8	0	0
No. 4.	Coal—Humph	0	3	4
	Strata—fakes	0	1	9
	Coal—Steel	0	2	6
	Strata—fakes, blaes, and ironstone ribs	5	0	0
No. 5.	Coal—Splint	0	3	5
	Strata—fakes and fireclay	1	2	8
	Coal—Virgin	0	3	0
	Strata—mostly red sandstone	6	0	0
No. 6.	Coal—Musselband	0	1	10
	Strata—mostly red sandstone	16	0	0
No. 7.	Coal—Lady Ha'	0	1	9
	Strata	7	0	0
No. 8.	Coal—Virtuewell or Fivequarter	0	3	0
	Strata	14	3	0
No. 9.	Coal—Shale, with musselband and oil-shale	0	1	3
	Strata	6	0	0
No. 10.	Coal—Kiltongue	0	4	0
	Strata	8	3	0
No. 11.	Coal	0	1	8
	Strata	3	6	0
No. 12.	Coal—Upper Drumgray	0	1	10
	Strata	5	0	0
No. 13.	Coal—Lower Drumgray	0	1	11
	Strata	9	0	0
No. 14.	Coal—Coxrod	0	1	11

The sections of the higher seams as given in the Coneypark Plantation Bore, put down in 1888, are as follows:—

		Ft.	In.
	Thick sandstone		
	Blaes	2	10
Coneypark Thick.	Coal	5	4
	Dark fakes and fireclay	2	8
	Coal	0	9
	Black coaly blaes	0	10
Coneypark Main.	Coal	3	3
	Dark fireclay	1	0
	Blaes and ironstones		

This bore cannot be far from the crop of these coals, and there is no information available as to the amount that remains to be worked in these seams.

		Ft.	In.
	Blaes with ironstone ribs		
Humph.	Coal	3	4
	Fakes and fireclay	1	9
Steel.	Coal (fine)	2	6
	Dark fakes		

There is believed to be a considerable area of the Humph Coal still to be worked: the lower seam does not appear to have been touched.

		Ft.	In.
	Black blaes and ironstone ribs		
SPLINT.	COAL	3	5
	Dark coaly blaes	0	8
	Dark fireclay	1	4
	Fakes and fireclay	5	8
VIRGIN.	COAL	3	0
	Dark fireclay and ironstone balls	3	6
	Red fakes and sandstone		

The Splint has been raised to a greater extent than the Humph; there may be still a good deal of the Virgin Coal unwrought.

The *Musselband Coal* is 1 ft. 8½ in. thick in the bore and is locally accompanied by a musselband ironstone. It underlies a thick bed of red sandstone and has a thin roof and floor of fireclay. Only a small area of this seam has been wrought by a cross-cut mine from the Splint workings.

The *Lady Ha'* and *Virtuewell*.—There appears to be a certain amount of confusion in the naming of these coals, the higher of which probably represents the Virtuewell of Lanarkshire.

In the cross-cut mine west of Banknock Station the thickness of the Lady Ha'—the upper seam, is given as 3 ft. 9 in., that of the lower seam—the Virtuewell, as 1 ft. 9 in. The section of the former in the Pumping Pit is as follows:—

	Ft.	In.
Sandstone		
Blaes	0	10
COAL	1	9
Fireclay	0	9
Bastard fireclay		

and of the latter on the old plans.

	Ft.	In.
Rock		
COAL	3	4
Fireclay		

It would thus appear that the thicker seam has been called the Lady Ha' in the mine and the Virtuewell in the older workings, while the Lady Ha' of the Pumping Pit is the thinner upper seam. This coal has been very little wrought: the lower seam or Virtuewell of the old workings has been worked over a large area, but a considerable amount of this seam must still remain untouched in the centre and eastern parts of the basin.

The *Shale Coal*.—This has been the most extensively wrought of the seams at Coneypark, and only a small area in the eastern part of the field remains unworked. The section is as follows:—

	Ft.	In.
Rock		
Black blaes	2	2
Oil-shale	0	5
Ironstone	0	7
COAL	1	1
Fireclay		

During the later years of the working of this field the oil-shale was taken out with the coal and distilled for petroleum. It is dark blue in colour, curls readily under the knife, and burns with a bright flame; it contains abundant plants, fragments of fish and shells of *Carbonicola.*

The available records of the *Kiltongue Coal* workings at Coneypark are very incomplete; it is believed to be a valuable seam, and its estimated thickness in the sections of the old shaft at Coneypark Farm ranges from 4½ to 5 ft. It has probably been worked over a large area from that pit or from the Pumping Pit.

The *Drumgray and Coxrod Coals.*—The West Pit is said to have been sunk to the Upper Drumgray seam (No. 12), but no workings exist in these coals except those in connection with the two mines at Jewelbank Cottage. These are driven from near the crops of the Coxrod and Lower Drumgray, but the Upper Drumgray has alone been worked to any extent. In the Air Pit connected with these workings a coal 1 ft. 8 in. thick is found, 4 fms. above the Upper Drumgray, which may represent the "Ell" of Banknock and Lower Splint of Dennyloanhead.

Section of Upper Drumgray.

	Ft.	In.
Rock		
Dark faky blaes	1	10
Dark fakes	0	6
Coal	1	10
Fireclay		

Section of Coxrod.

	Ft.	In.
Faky fireclay		
Coal	1	11
Fireclay		

Banknock.

The fault which separates the Coneypark and Banknock workings decreases from N.W. to S.E., and probably dies out before reaching the southern boundary of the outlier. To the west of the Victoria Pit this fault brings the Virtuewell (8) against the Splint and Virgin (5), a throw of about 30 fms. The Victoria Pit is sunk in the deepest part of the Banknock basin to the Virtuewell at a depth of 53 fms.; it is therefore probable that some of the higher seams are present in a small area round this pit. Unfortunately no detailed section of this shaft is available.

The workings at Banknock and those at Dennyloanhead—next to be described—are better known than those of Coneypark, for the reason that coal is still being raised in these areas; a number of bores have also been put down, the details of which have been kindly placed at the disposal of the Survey by the Banknock Coal Company.

The Banknock workings were formerly supposed to be separated from those of Dennyloanhead by a large fault, which is represented on the original Geological Survey map as crossing the field from N.N.E. to S.S.W. between Shielyards and Dennyloanhead Station. Later operations have, however, proved that the supposed direction and magnitude of this fault were erroneous.

In recent times mining operations have been carried on from the Victoria, Livingstone and Cannerton Pits and from the Banknock Mine.

Until lately all the seams from the Shale Coal above the Kiltongue down to the 3rd Drumgray or Ball Coal were wrought at Banknock; the higher seams are, however, almost exhausted, and the coals chiefly raised at the present time are the Splint, Upper and Lower Drumgray and Ball Coals.

The general section of the Banknock workings is as follows, the *local* names are given for the coals:—

		Fms.	Ft.	In.
	Strata—largely red sandstones			
No. 8.	Coal—Virtuewell or Fivequarter	0	3	6
	Strata	17	0	0
No. 9.	Coal—Shale	0	1	8
	Strata	5	3	0
No. 10.	Coal—Banknock or Kiltongue	0	4	0
	Strata	3	0	0
No. 11.	Coal—Ell or Pavement	0	1	8
	Strata	5	0	0
No. 12.	Coal—Splint	0	2	0
	Strata	4	3	0
No. 13.	Coal—Banknock Jewel	0	2	0
	Strata	6	0	0
No. 14.	Coal—Upper Drumgray or Dirt	0	1	2
	Strata	0	2–8	0
No. 15.	Coal—Lower Drumgray	0	1	0
	Strata	5	0	0
No. 16.	Coal—Soft	0	1	8
	Strata	5	0	0
No. 17.	Coal—3rd Drumgray or Ball	0	2	0
	Strata—with 3 Coals	30	0	0

The coal shown in this section between the Lower and 3rd Drumgrays is known locally as the Soft Coal; it is overlain by dark blaes with ironstone ribs, and sometimes contains a band of cannel coal; it has been considered to lie on the horizon of the Mill Coal of the Carron field.

A comparison of the sections of that field with those of Banknock, however, favours the correlation of the Soft Coal with the Coal and Shell-band which lies between the Coxrod and the Mill Coal of Carron; and of the 3rd Drumgray, which is overlain by an ironstone, with the Mill or Auchingane.

The *Virtuewell* (8) was formerly worked as a good house coal. The seam was 40 inches thick.

The *Shale Coal* (9) is a second-class house or gas coal. It is rich in gas, but is a free coal and does not swell in coking.

The section of the seam is as follows:—

	Ft.	In.
Musselband ironstone	0	1–1½
Oil-shale	0	9
Musselband ironstone	0	5–8
Black blaes	0	3–8
Coal	20 in. to 2	8
Fireclay		

The *Banknock Main or Kiltongue* is a good house coal, 4 to 5 ft. in thickness; the roof is of faky blaes, the floor a fireclay about 2 ft. thick. The *Ell* or *Pavement Coal*, 14 to 16 inches in thickness, has been locally worked; it is inferior in quality to the Main Coal, of which it forms the lower leaf; the distance between these two seams increases eastwards from less than one to 3 fathoms, the Ell coal of Banknock becoming the Blackband or Lower Splint of Dennyloanhead.

The *Splint* (12) is still worked as a furnace coal at Banknock: it is considered to be the equivalent of the Main Coal of Carron.

Section—	Ft.	In.
Sandstone		
Black blaes	4	0
Musselband	0	6
Blaes and ironstone ribs	4	0
COAL	2	3
Fireclay		

The *Banknock Jewel Coal* (13) averages 2 ft. in thickness at Banknock, where it is raised as a house coal. It is variable and of little value elsewhere in the Banknock field or at Carron, where it is known as the Mid Splint.

The *Upper and Lower Drumgrays* (14, 15) lie close together: often separated by less than 2 ft. of strata. They are usually worked together, in the following section:—

	Ft.	In.
Fireclay		
COAL	1	2
Black "sclitt"	0	7
Fireclay	0	11
COAL	1	0
Rock		

The *3rd Drumgray or Ball* is a household coal. Section as follows:—

	Ft.	In.
Rock		
Fakes	1	9
Blaes and ironstones	2	6
COAL, soft	0	10
COAL, hard	0	6
COAL, free	0	10½
Daugh	0	1½
COAL	0	3
Fireclay		

Dennyloanhead.

This section of the field includes the two basins of Broomrigg and Bonnyrigg. The higher coal seams in the former basin have been almost worked out from the Garibaldi and the two Broomrigg Pits.

The New Broomrigg Shaft, on the side of the railway immediately west of Dennyloanhead, passes through all the seams from No. 1 (Ell) to No. 12 (Upper Drumgray) at 109 fms. A bore from the bottom of the pit continues the section to No. 17—the Ball or 3rd Drumgray of Banknock—at a depth of 132 fms.

The highest seam met with in the Bonnyrigg Pit, sunk in the centre of the basin of that name, is No. 4—the Hard or Main Coal; this shaft reaches the Upper Drumgray at 92 fms.

The Knowehead Pit and Mine, situated 400 feet N.E. of Dennyloanhead Station, have been sunk in recent years, the former reaching No. 4 (Main) at 20 fms. The mine, driven to the N.W. at an angle of 1 in 3½, met the rock-head after passing through 372 feet of drift. The depth of surface deposits at this point is estimated at 32 fms., and the steep contours of the surface-relief between Dennyloanhead and Jenny Lind Cottage are entirely due to drift accumulation. The mine was expected to meet the large N.N.E.-S.S.W. fault already referred to, p. 51, but the workings in the Ladygrange (Jewel) Coal have proved this fault to have the direction shown on the revised edition of the map.

GENERAL SECTION OF THE STRATA IN THE DENNYLOANHEAD FIELD, WITH LOCAL NAMES OF SEAMS.

		Fms.	Ft.	In.
	Strata	31	0	0
No. 1.	COAL—ELL	0	4	0
	Strata	5	0	0
No. 2.	COAL—SOFT	0	1	4
	Strata	2–4	0	0
No. 3.	COAL—SPLINT	0	2	6
	Strata	6–8	0	0
No. 4.	COAL—HARD OR MAIN	0	3	0
	Strata, with ironstone or musselband	8	0	0
No. 5.	COAL—HUMPH OR SPLINT	0 0	1 to 2	1 6
	Strata	2	0	0
	COAL—(SPLINT OR VIRGIN ?)	0	1	4
	Strata	10–12	0	0
No. 6.	COAL—MUSSELBAND position	0	1	0
	Strata, chiefly red sandstones with ironstone position			
No. 7.	COAL—VIRTUEWELL	0	3	5
	Strata	5–6	0	0
No. 8.	COAL—LADYGRANGE (sometimes known as "Jewel")	0	3	0
	Strata	9–16	0	0
No. 9.	COAL—SHALE	0	1	11
	Strata	5	3	0
No. 10.	COAL—KILTONGUE	0	2	8
	Strata	3–7	0	0
No. 11.	COAL—LOWER SPLINT OR BLACKBAND	0	3	6
	Strata	3–4	0	0
No. 12.	COAL—UPPER DRUMGRAY	0	3	4
	Strata	6	0	0
No. 13.	COAL—MID DRUMGRAY			
	Strata	5	3	0
No. 14.	COAL—	0	1	2½
	Strata	1	2	0
No. 15.	COAL—LOWER DRUMGRAY	0	1	8½
	Strata	5	0	0
No. 16.	COAL—			
	Strata	4	0	0
No. 17.	COAL—BALL	0	1	5

The sections of the upper seams—as given on the old plans—are as follows:—

No. 2.—*Soft Coal,* a house coal.

	Ft.	In.
Rock		
Soft COAL	1	4
Daugh	0	3
Bastard fireclay	2	6

No. 3. *Splint,* a furnace coal.

	Ft.	In.
Fakes		
Faky blaes brushing	2	6
SPLINT COAL	2	2

No. 4. *Hard,* a house coal.

	Ft.	In.
Fakes		
Blaes, brushing		
Blaes	0	2
WILD COAL	0	4
HARD COAL	3	0
Daugh	0	3
Fireclay		

This seam (4) is called the Main Coal at Knowehead, where the section is—

	Ft.	In.
Rock		
Blaes (variable)		
COAL	2	7
Daugh	0	4
Fireclay		

A musselband, in several leaves, over 1 ft. thick, lies 4 fms. below No. 4 Coal; a clayband ironstone, 2 ft. in thickness, is found in the same position in the bores near Dennyloanhead.

The section of No. 5 coal at Knowehead, where it is known as the *Humph or Splint,* and worked as a furnace coal, is—

	Ft.	In.
Fakes		
Fakes	0	10
COAL	1	1
Fireclay	1	10
COAL	1	4
Fakes		

It does not appear to have been wrought further to the east. No. 6, the Virgin of Knowehead Bore, is the Splint Coal of the Broomrigg and Bonnyrigg shaft sections: it is doubtful whether this seam represents the No. 6 or Musselband of Coneypark or may not be the lower half of No 5: the latter correlation seems more probable. Section of the Virgin at Knowehead—

	Ft.	In.
Blaes		
COAL	1	8
Blaes		

Of the Splint at Bonnyrigg—

	Ft.	In.
Blaes		
Stone	0	4
COAL	2	6
Stone	0	2
COAL	0	6
Daugh	0	2
Fireclay		

A diamond bore put down at Banknock in 1911 proved 16 fms. of red sandstones and marls above the Virtuewell, 2 ft. 6 in. thick; the Ladygrange, 2 ft. 3 in., lay 8 fms. below. The Shielyards bore No. 6, put down 400 ft. further south in 1910, showed a 1 ft. coal 7 fms. above the Virtuewell, followed above by 9 fms. of red sandstone. The strata between No. 4 and No. 7 (Virtuewell) seem to be somewhat variable in character, but red sandstones are almost always met with in this position throughout the Banknock and Carron fields. As already suggested, there seems to be here a break in the usual Coal Measure sequence, probably accompanying a change in the conditions of deposit.

The section of the *Virtuewell*, worked as a steam coal at Bonnyrigg, is as follows:—

	Ft.	In.
Hard fireclay		
Coaly sclitt	0	6
Coal	1	4
Soft Coal	0	10
Coal	1	3
Daugh	0	2
Fireclay		

The *Ladygrange* is a good house coal: Section at Knowehead—

	Ft.	In.
Rock		
Coal	0	5
Dirt		
Coal	2	9
Daugh	0	3
Fakes		

Section at Bonnyrigg—

	Ft.	In.
Rock		
Coal	0	4
Sclitt	0	1
Coal	3	0
Daugh	0	3
Fireclay		

Shale Coal—a house coal. Section at Bonnyrigg—

	Ft.	In.
"Wild shale"	3	0
Oil-shale	0	9
Blaes and ironstone ribs	1	0
Coal	1	11
Fireclay	0	6

Kiltongue—a steam and furnace coal. Section at Bonnyrigg—

	Ft.	In.
Rock		
Blaes	4	0
Coal	0	8
Sclitt	0	2
Coal	2	8
Sclitt	0	2
Daugh	0	6
Fireclay		

The *Lower Splint* or *Blackband* is an inferior steam coal. Section—

	Ft.	In.
Blaes		
Blaes	1	6
Coal	3	6
Daugh	0	3
Bastard fireclay		

The *Upper Drumgray* is a furnace coal, partly free and partly splint.

	Ft.	In.
Blaes with a musselband		
Stone	0	3
COAL	3	4
Fireclay		

The lower coals have not yet been worked, but, as already shown, have been proved in a blind bore at the New Broomrigg Shaft: the Knowehead Mine has now (1913) been driven to the Lower Drumgray.

The Dennyloanhead workings are bounded on the north by an upthrow fault which runs in an E.S.E direction from the boundary fault near Wester Bankhead; this fault has been proved in the Ladygrange Coal as far east as Wester Bonnyfield. Another fault with a contrary throw, proved in the same seam, extends E.N.E. from the southern boundary of the field near the Garibaldi Pit. A mine driven through this fault from the Bonnyrigg Splint Coal workings to the Ladygrange proved the northerly downthrow at this point to be 20 fms.

The triangular area between this fault and the southern boundary of the Coal Measures has been proved by several bores, and is at the time of writing being worked for the Ladygrange Coal. The beds dip north-west and include coals up to No. 5 of the Knowehead sequence.

The position of these bores and the depths of the different coal seams passed through are indicated on the revised edition of the Quarter Sheet Stirling, 29 N.E.: the following section gives the general sequence of the beds in this area :—

		Fms.	Ft.	In.
	Strata	3	0	0
HUMPH NO. 5 ? OR SPLINT	COAL	0	1	6
	Strata	3	0	0
	COAL	0	0	6
	Strata	5	0	0
SPLINT OR VIRGIN ? COAL		0	1	2
	Strata	22	0	0
VIRTUEWELL NO. 7 COAL		0	2	10
	Strata	8	0	0
LADYGRANGE NO. 8 COAL (Jewel)		0	3	6
	Strata	14	0	0
SHALE NO. 9 COAL		0	1	0
	Strata	6	0	0
KILTONGUE NO. 10 COAL		0	3	2
	Strata	5½	0	0
LOWER SPLINT NO. 11 COAL		0	1	11
	Strata	5	0	0
UPPER DRUMGRAY NO. 12 COAL		0	3	1
	Strata	4	0	0
MIDDLE DRUMGRAY NO. 13 COAL		0	3	5
	Strata	4	0	0
LOWER DRUMGRAY NO. 15 COAL		0	2	6
	Strata			

The other triangular area which lies between the Bankhead and northern boundary faults and extends westward from Bonnybridge to Western Bankhead, though extensively bored, has not yet (1913) been worked. The journals of the bores put down in this area indicate that the strata are probably arranged in two small basins, corresponding to those of Broomrigg and Bonnybridge further south. The deepest part of the broad eastern extremity of the field lies near the position of the diamond bore recently put down to the west of Ure Allan Park, Wheatlands; this bore proved the Shale Coal (No. 9) at 11 fms. from rock-head, and passed through all the seams down to a coal at 56 fms., about 19 fms. below the supposed position of the Lower Drumgray (No. 15). C. B. C.

The Carmuirs Field.

(Stirling, 24 S.W.; 30 N.W.)

The Carmuirs workings are situated between Larbert and Camelon, a little more than ½ mile east by south of Larbert Junction. The coals lie in a trough between two roughly parallel east-and-west faults, the probable continuations of the dislocations which bound the Banknock field, already described. The northern fault passes about 1000 ft. north of the Carmuirs Pits and extends in an E.N.E. direction by Dorrator and Longlees to the Carron at Kerse Bridge, where it converges to meet the southern boundary-fault. The latter line of fracture lies 2000 feet south of the pits and runs through Bainsford to Kerse Bridge, whence it passes out to sea at Grangemouth.

The narrow strip of ground between these faults is probably occupied by Coal Measures as far west as Carmuirs, an anticlinal fold between that point and Bonnybridge bringing up the Millstone Grit which separates the Banknock and Carmuirs coalfields. A curving fault with downthrow to the south leaves the northern boundary fault near Larbert Junction, and, passing immediately south of the shafts, limits the workings of the lower seams in that direction.

The area is completely and deeply covered with superficial deposits, and no natural sections are visible, but the information supplied by the numerous bores put down over the field, and by the plans of the Carmuirs workings, shows that the dip of the beds is mainly in a northerly direction. Near the pit-shafts the strata form a dome, the Crow Coal or Kiltongue on the upthrow side of the fault referred to in the preceding paragraph dipping north-west, north and north-east, followed by the crop of the Carron 2-Foot, or Shale Coal of Banknock. On the south side of this fault the extent of the Crow Coal is greater, but both this seam and the one next below it—the Splint, Upper Drumgray or Carron Main—come to the surface before reaching the southern boundary of the field.

Further to the west the strike probably swings round to the north, and the lower coals crop out, beneath the thick covering of drift, somewhere to the west of Carmuirs House.

On the east side of the present workings in the direction of Dorrator, the Carron 2-Foot and higher seams are probably brought up again on a synclinal fold, but this part of the field has not yet (1913) been proved.

The coals raised at the Carmuirs Colliery up to the year 1907 (when the workings were unfortunately flooded) were known as the

Kiltongue (Crow Coal), Upper and Lower Drumgray. These were wrought as house and steam coals.

The sections of the seams are as follows:—

		Ft.	In.
	Rock	3	0
Kiltongue	Coal	1	11
	Dirt	0	4
	Coal	0	5
	Bastard fireclay	0	0

		Ft.	In.
	Musselband		
Upper Drumgray	Black blaes	2	2
	Shale	0	3
	Coal	3	8
	Daugh	0	5
	Sandstone		

		Ft.	In.
	Rock		
Lower Drumgray	Fakes	1	4
	Coal	2	6
	Daugh	0	2

The following section of the strata in this field has been drawn up from the bore journals kindly placed at the disposal of the Survey.

	Fms.	Ft.	In.
Coal—Virtuewell	0	2	5
Strata	2	3	0
Coal—Ladygrange	0	1	10
Strata	20	0	0
Coal—Carron Two-foot or Shale	0	2	2
Strata	8	0	0
Coal—Crow Coal or Kiltongue	0	2	4
Strata	5	0	0
Coal	0	1	2
Strata	4	0	0
Coal—Splint, Carron Main or Upper Drumgray	0	3	8
Strata	6	0	0
Coal—Lower Drumgray—Coxrod of Carron ?	0	2	6
Strata	3	0	0
Coal—Lower Coxrod of Carron	0	1	9
Strata	6	0	0
Coal and Ironstone—Shell-band of Carron	0	1	9
Strata	6	0	0
Coal and Ironstone—Mill Coal of Carron ?	0	1	6
Strata	12	0	0
Coal—Glenfuir of Carron	0	1	2
Strata	10	0	0
Coal—Colinburn of Carron	0	1	6
Strata	1	0	0
Ironstone and Coal position. Ballstone ?			
Strata	4	0	0
Coal position			
Strata	10	0	0
Coal	0	1	1
Strata, chiefly sandstone	7	0	0

Carron, Grangemouth and Airth.

(Stirling, 24 N.E., S.E.; 25 N.W., S.W.)

The Coal Measures of this area underlie the wide carse and drift deposits that extend between Airth and Falkirk, on the south side of the Firth of Forth. They are continuous with the Falkirk and Slamannan coalfields on the south, and to the north and north-east pass beneath the Forth to join those of Kincardine and Clackmannan. The area is thus of importance as affording a means of correlation between the Coal Measures of the Lanarkshire basin and those of West Fife.

The ground is for the most part deeply covered with superficial material, and only in one or two places near Airth and Stenhousemuir are limited sections of the Coal Measures exposed. Further to the west, between Larbert and Torwood, the underlying Millstone Grit strata are visible in a number of quarries and natural sections.

The Coal Measures occupy a shallow basin with a mean breadth of about six miles, the Millstone Grit appearing again on the eastern side of the Forth between Culross and Longannet Point.

The inclination of the beds on either side of the syncline is very gentle, and over a wide area in the centre of the basin the coal seams are lying almost flat. In spite of the favourable disposition of the strata the coals have been found difficult to reach on account of the great depth and loose nature of the carse deposits above the rock-head.

The field is traversed by a number of roughly parallel faults with a general east and west trend. The larger dislocations, some of which have a throw of 20 to 30 fms. to north or south, completely cross the field, while others with a lesser throw in the same direction diverge at a small angle from these major faults. An east-and-west dolerite dyke, probably in continuity with the intrusion that crosses the Denny area (see p. 17), traverses the Carron and Grangemouth workings, and has burnt the coals. Its course through the Carron field as far east as Carronshore lies in a narrow "*horst*" or elevated fault-block between two of the east-and-west dislocations.

Horizontal sections drawn across the basin from east to west parallel to the major faults show the strata lying at gentle angles in a shallow basin with little faulting. Those drawn from north to south reveal, however, a series of raised and depressed fault-blocks in which the dip of the beds has been to some extent affected by movement during the faulting.

The structure is, in fact, a repetition of that met with in all the coalfields along the south side of the Campsie Fells, where a system of folding along axes with an approximate north and south trend has been modified by subsequent faulting.*

The structures due to this double series of movements, though very complex in the Riggin at Kilsyth, Banknock and elsewhere, are, in the case of the area at present under consideration, of a simple nature. C. B. C.

The Carron and Grangemouth Coalfield.

The workings of the Carron and Grangemouth collieries are separated from those of the Airth field by the east-and-west fault which passes immediately to the north of Kinnaird and Stonehouse: the divisional line between the two former workings is an artificial one, and approximately follows the high road from Kerse to Airth.

The southern boundary of the workable coals is somewhat uncertain; it is probably indicated by the fault, with downthrow to north, that passes into the Firth at Grangemouth, and forms the eastern extension of the line of dislocation bounding the Carmuirs and Banknock fields on the south. East of Kerse Bridge the Grangemouth workings are limited by this fault, which is believed to bring down the Coal Measures against the Millstone Grit beneath the alluvial deposits of the Forth. West of Kerse Bridge the Carron workings are at present limited on the south by another fault, throwing to south, which passes through Longlees and Dorrator, and is continued westwards as the northern boundary of the Banknock outlier.

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* "The Geology of the Glasgow District" (*Mem. Geol. Survey*), 1911, pp. 154–156.

The narrow trough of Coal Measures, thus let down between these two faults, is probably continuous with the Carmuirs area further to the west.

The deepest part of this field lies around Kinnaird, where the Virtuewell Coal was at one time worked over a small area. On either side of the basin the successive coal seams come to the surface, but the position of the outcrops is much affected by the displacements caused by the east-and-west faults which cross the field. Of these dislocations the following are the most important:—

1. The Kinnaird fault, with downthrow to south, starts immediately west of Kinnaird and, rapidly increasing eastwards in amount of throw up to 20 fms., passes north of the Carronhall William Pit, and runs out to sea near Orchardhead.

2. The Carronhall fault enters the field near North Broomage, and extends south of Carronhall and Howkerse to the sea, at a point a short distance south of the Palace Pit of Grangemouth workings, where it probably meets the Kinnaird fault, No. 1. The throw of this fault to the south is about 17 fms.

3. Two small faults with contrary throws extend east on either side of the dolerite dyke from Stenhousemuir to Carronshore, but are not continued into the Grangemouth field.

General Section of the Strata in the Carron and Grangemouth Field, giving the Local Names of the Different Seams.

	Fms.	Ft.	In.
Strata—with coals only known south of the Banknock—Carmuirs fault	30	0	0
Coal—Virtuewell	0	2	2
Strata	2	3	0
Coal—Ladygrange ?	0	2	8
Strata—with ironstones and musselband	20	0	0
Coal—underlying musselband—Miller or "Two-foot Coal" of Carron—"Thin Coal" of Grangemouth =Kiltongue Musselband	0	2	0
Strata	5	3	0
Coal—Crow Coal or Kiltongue	0	2	9
Strata	9	0	0
Coal with musselband above—Carron Main or Upper Drumgray	0	3	0
Strata	5	0	0
Coal—Mid Splint			
Strata	7	0	0
Coal—Upper Coxrod—in 2 or 3 bands with stone partings	0	2–3	0
Strata	1–2	0	0
Coal—Lower Coxrod	0	2	0
Strata—chiefly blaes and ironstones	5	0	0

	Fms.	Ft.	In.
COAL and musselband—"SHELL BAND"			
(A constant horizon throughout this and the Airth field).			
Strata—chiefly blaes and ironstones	5	0	0
COAL—MILL or AUCHINGANE=CLEFTED COAL with ironstone and "parrot" above			
Strata	6	0	0
COAL—inconstant—BRIGHTON MAIN ?			
Strata—chiefly sandstone	5	0	0
COAL—GLENFUIR or ARMADALE MAIN			
Strata—chiefly sandstone	9–10	0	0
COAL—COLINBURN			
Strata—chiefly sandstone	6	0	0
IRONSTONE—inconstant			
Strata—chiefly sandstones and fireclays with one or two thin inconstant coals			

A deep pre-glacial channel, filled with surface deposits to a depth of at least 40 fms., traverses the field from east to west beneath the present course of the river Carron, and completely interrupts the continuity of all the coals whose maximum depth is less than that figure. These are the Main, Crow and Thin Coals, which have been worked up to the crop along the side of the channel. The Coxrod and lower seams underlie the floor of the buried valley. (See also Chapter V., p. 85)

The coals most extensively wrought at Carron have been the Crow, Main, Upper and Lower Coxrod seams. The 2-Foot Coal has been worked over a considerable area in the northern part of the field, and the Virtuewell was at one time raised from the Kinnaird Pits.

The Crow Coal is a house coal: the Main Coal is in two parts—a splint coal which is used with coke in blast furnaces, and a softer coal raised as a steam coal: the Coxrod seams are also steam coals. Altogether about one-fifth of the coals wrought in this field are for household purposes; the remainder are steam and furnace coals.

C. B. C.

The Airth Coalfield.

Only that part of the area which lies to the south of the village of Airth is referred to in this Memoir; the northern extension of the field will be included in a future description of the Kincardine coalfield.

The ground north of the Kinnaird fault, which bounds the Carron and Grangemouth field, has been extensively bored in recent years by Carron Company, who have lately (1911) sunk pits at the side of the Airth Road, ½ mile south of Airth Castle, to the Lower Coxrod Coal.

The underground information obtained throughout the field supplies the following general section of the strata; this is, as will be seen, closely similar to the corresponding part of the sequence in the Carron-Grangemouth field.

	Fms.	Ft.	In.
Strata			
CROW COAL	0	3	0
Strata	6	3	0
COAL with musselband above=CARRON MAIN	0	3	0
Strata	6	3	0
COAL—MID SPLINT	0	1	6
Strata	7	0	0

	Fms.	Ft.	In.
COAL—UPPER COXROD	0	1	9
Strata	2	0	0
COAL—LOWER COXROD	0	2	0
Strata—chiefly blaes with ironstones	7	0	0
Shellband—constant throughout the field			
Strata—chiefly blaes with ironstones	5	0	0
COAL—MILL, with parrot roof	0	1	10
Strata	4	0	0
COAL—inconstant—BRIGHTON MAIN POSITION			
Strata—chiefly sandstone	9	0	0
COAL—GLENFUIR or ARMADALE MAIN	0	2	6
Strata—chiefly sandstone	7	0	0
COAL—COLINBURN . . . . 1 ft. 6 in. to	0	2	0
Strata	6	0	0

The bore journals also show that, as in the fields further to the south, the area is crossed by a series of parallel east-and-west faults.

A branch fault from the dislocation which forms the northern limit of the Carron field crosses the Airth field between South Letham and Mains of Powfoulis. The 25-fm. displacement of the boundary-fault to the south is sufficient to throw out the Virtuewell, 2-Foot and Crow Coals in the area between these two lines of disturbance, but a small truncated basin of the Carron Main occupies the ground immediately south of Southfield, together with a larger field of the Coxrod and lower seams. Further to the north another large fault, the Letham fault, extends due east from Letham Moss in the direction of Bowtrees, crossing the field at an approximate distance of 100 yds. south of the New Airth Pits. The downthrow of this fault is to the north, and the area between it and the next fault to the south is consequently a "horst," or raised fault-block, in which all the coals above the Lower Coxrod are absent, while that seam only occupies a small area south of Lochs of Airth. The Mill Coal covers a wider field, but both this and the lower seams appear from the bore section to be of small thickness in this area.

The downthrow of the Letham fault to the north must be large in amount, since beyond it the Carron Main Coal appears, forming a basin south of Airth Castle more than half a square mile in extent; this is followed on either side by the crop of the Coxrods, Mill and lower seams, the whole coal basin measuring fully 3 miles from east to west.

The position of the base of the Coal Measures in the raised fault-block referred to above lies somewhere about the centre of the Letham Moss.

The whole of this district is deeply covered with superficial deposits.

The sections of the seams formerly worked in the pits at and around Airth were as follows:—

At the Dunmore Pits, near Bridgend, south of Airth Station.

Coal given on the plans as the "Coxrod," but now correlated with the Colinburn.*

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* This coal is correlated on the published map with the Glenfuir, but there is good reason to believe that the correlation given above is more likely to be correct.

		Ft.	In.
	Wild Coal		
Colinburn	Fireclay	0	10
	Coal	0	1
	Fireclay	2	4
	Coal	2	2
	Fireclay		

Sections of three coals formerly wrought at the Airth Pits, E. of Airth Castle. At No. 1 Pit, close to Airth Mill—

		Ft.	In.
The "Upper Coal" at 7½ fms.	Coal	2	0
	Daugh	0	6
	Fireclay	0	2½

		Ft.	In.
"Ball Coal," at 19 fms.	Blaes and ironstone	3	10
	Parrot Coal	0	3
	Coal	1	10
	Fireclay	0	1½

At No. 2 Pit, 400 yds. north-east of Airth, the "Ball" Coal was got at 17 fms.: the "Main" Coal at 35 fms. The section was—

		Ft.	In.
	Faky fireclay	1	6
"Main" Coal	Coal	0	4
	Sclit	0	3
	Coal	0	10
	White stone	0	1
	Coal	1	3

The coals raised from these pits are now correlated as follows:—The "Upper" Coal is the equivalent of the Lower Coxrod; the "Ball" Coal of the Mill; and the "Main" Coal of the Glenfuir or Armadale Main. C. B. C.

The Falkirk Coalfield.

(Stirling, 30 N.W., N.E., S.W., S.E.; 31 N.W., S.W.; 34 N.E.)

The term Falkirk Coalfield is applied in this Memoir to an extensive area of Coal Measures, including the districts of Polmont, Brightons, Muiravonside, Shieldhill, Jawcraig and Bonnyhill, as well as the immediate neighbourhood of Falkirk. Southwards it is bounded by the Lenzie-Torphichen dyke. Eastwards and westwards it is limited by the outcrop of the underlying Millstone Grit, and extends northwards to the fault which forms the southern boundary of the Carmuirs coalfield.

So far as the higher seams are concerned, the area under description forms a more or less quadrangular basin, the beds dipping on the four sides to N., S., E. and W. The chief modification of this structure is introduced by the east-and-west fault, which repeats the crops of the Splint and Coxrod Coals about half a mile south of Falkirk. Within the area as a whole there are 15 workable coal seams, though the highest of these are only present over a limited area, and some of the lower ones are impersistent.

In the following vertical section the seams down to the Armadale Main represent an approximate average. The lowest members of the sequence (up to the Highstone) are shown, with the thickness and relative position which they have at Bonnyhill, on the north-western margin of the basin.

Section of the Falkirk Coalfield.

	Thickness.			Depth.		
	Fms.	Ft.	In.	Fms.	Ft.	In.
Wee Coal	0	2	0	0	0	0
Strata						
Diamond or Cockmalane Coal	0	4	0	2	0	0
Strata						
Miller, or Carron Two-Foot Coal	0	1	0	13	0	0
Strata						
Crow Coal	0	1	0	22	0	0
Strata						
Splint or Upper Drumgray Coal	0	2	6	30	0	0
Strata						
Mid Coal (near Craigend only)	0	2	0	33	3	0
Strata						
Coxrod or Lower Drumgray Coal	0	2	6	43	0	0
Strata						
Low Coxrod or Balmoral Coal	0	1	0	47	0	0
Strata						
Mill or Auchingane Coal—						
Parrot	0	0	4			
Free Coal	0	1	8	58	0	0
Strata						
Ball or Brighton Main Coal	0	2	0	65	0	0
Strata						
Armadale Main, Gutterhole or Glenfuir Coal	0	2	6	70	0	0
Strata						
Highstone (Clayband Ironstone)	0	0	4	79	2	9
Fireclay	0	2	3	79	5	0
Highstone Coal	0	1	0	80	0	0
Strata, including 3 fms. sandstone	3	3	9	83	3	9
Bonnyhill Craw Coal	0	1	0	83	4	9
Strata	1	0	0	84	4	9
Lowstone (Ironstone Balls)	0	0	6	84	5	3
Blaes	0	1	0	85	0	3
Lowstone Coal	0	1	0	85	1	3
Strata	1	5	0	87	0	3
Fireclay	1	0	0	88	0	3
Slatyband Ironstone: Ironstone (Blackband)	0	1	9	88	2	0
Daugh	0	0	3	88	2	3
Ironstone (Blackband)	0	1	2	88	3	5

Slatyband Ironstone.—A slatyband at the base of the Coal Measures has been wrought at various localities along the western edge of the coalfield: its relations are best known near Bonnyhill. In the railway cutting east of Fauchlands (at the north end of the Tentfield plantation) its position is represented by 8 in. of coal. In the Roughcastle fireclay workings this coal is overlain by from 0 to 6 in. of blackband ironstone, occasionally rising to 18 in. in "lunkers." The ironstone must have been of better quality in the near vicinity, as it was mined by Carron Company from an old day-level just south of the fireclay works. The seam was also wrought to the west of Loanfoot, where the section showed—

	In.
Rock roof	
Blaes, brushing	42
Coal	2
Blackband Ironstone	13
Rock pavement	

There were also a large number of shallow pits to this ironstone near Beam and Garbethill. A bore near the latter locality shows—

	In.
Fakes	
Dark blaes and COAL	10
Good hard IRONSTONE	11½
Soft ply or parting	½
Hard, good, clean IRONSTONE	15½
Hard fakes, pavement	8

The ironstone is stated to have been 3 ft. thick in one of the Garbethill pits.

So far as is known this seam has never been met with in, and is probably absent from, the central part of the Falkirk coalfield. East of Polmont, however, a blackband ironstone was at one time exposed in the Millhall Burn. It is recorded as full of *Lingula*, together with other marine fossils, and as having a blaes roof, but nothing seems to be known as to its thickness and character. An old day-hole may be seen in the vicinity, but it is uncertain whether it was connected with this particular seam. The presence of marine fossils might serve to identify this ironstone either with the Crofthead Slatyband or with the slightly higher Slatyband of Armadale: the seam wrought on the west side of the basin is more probably the former.

The fireclay (5 ft. thick) overlying the Bonnyhill Slatyband is wrought by a day-level and used in the adjacent Roughcastle fireclay works. In pre-war times there was a considerable export trade in this material, the ground fireclay going to South America chiefly for mixing with ganister in the manufacture of fire bricks for furnace linings.

Lowstone, Bonnyhill Craw Coal, and Highstone.—The Lowstone position and the Bonnyhill Craw Coal are both well seen in the Fauchlands railway cutting. The former is underlain by a foot of hard splinty coal (the Lowstone Coal). The blaes which contains the ironstone balls is characterized by the presence of a marine fauna, *Lingula* and *Conularia quadrisulcata* having been collected from this horizon. The Bonnyhill Craw Coal is a foot in thickness, and is immediately overlain by a post of sandstone. The Highstone Coal and Ironstone are not seen in the cutting, but were formerly wrought together with the lower seams in several pits in the Tentfield Plantation.

The coal below the Lowstone is a persistent feature, but is not usually more than 6 or 7 in. thick. The Bonnyhill Craw Coal ranges from a foot to 1 ft. 3 in., and has always its sandstone roof. It was probably the latter seam which was wrought above the Slatyband at Loanfoot, where it is 18 in. in thickness. Further south it is thinner, but is recorded as 16 in. in the bore near Garbethill already referred to.

Two old pits close to Glenvale Cottage are stated to be just on the crop of a 14-in. coal, and to have been sunk to another of 22 in. at a depth of four fathoms. The latter is overlain by a thick post of "rock," and so may quite possibly represent the Bonnyhill Craw Coal. In this case the overlying coal must be the Highstone, although there is no record of any accompanying ironstone.

Further south there is a record of at least two pits from which clayband ironstone was formerly raised near Todbughts, just to the north of the dolerite dyke. In one case it is stated that the seam worked was a ball ironstone lying just above the position of the Slatyband. Assuming that the latter was correctly identified, the former would possibly correspond to the Lowstone.

A ganister or fireclay of some economic value immediately underlies the Bonnyhill Craw Coal. The seam, 18 in. in thickness, is usually a strong, firm, somewhat sandy fireclay, but passes locally into a ganister of good quality, closely resembling the ganisters of the Bonnybridge district.

This seam is wrought at Roughcastle, and the material supplied to steel works both in the wet and dry ground condition.

No member of this group of minerals appears to be well developed in the central or deepest part of the Falkirk coalfield, but a bore put down at Messrs. James Aitken & Co's. Brewery, Falkirk, records the following section:—

	Fms.	Ft.	In.
Sandstone	1	5	0
COAL	0	1	1
Fireclay	0	1	9
White sandstone	4	1	0
Faky sandstone	0	1	6
COAL	0	1	4
Faky fireclay	0	5	0
Ball ironstone	0	0	1
COAL and fireclay	0	1	7

The 1 ft. 1 in. coal lies about 10 fms. below the Armadale Main in the bore section, and is probably the Highstone, while the 1 ft. 4 in. seam corresponds well in position with the Bonnyhill Craw Coal.

Sulphur and Colinburn Coals.—A coal named the Colinburn has been wrought at one or two localities on the east side of the basin. Near Polmont Junction it is known from a number of bores to have an average thickness of at least 18 in. It was wrought at No. 2 Pit, Manuelrig, where the section was—

	Ft.	In.
Faky blaes	3	0
Fireclay	0	2
FREE COAL	1	3
Splinty COAL	0	5
Daugh	0	2
Fireclay pavement		

This was almost certainly the seam which was wrought from an old pit near Wester Bowhouse, under the name of the Speckle Ball. Here the section was—

	Ft.	In.
Ironstone	0	4
Parrot	0	9
FREE COAL	2	0
Fireclay	2	0
RED COAL	1	6

The term Speckle Ball refers to the ironstone forming the roof. Further south the Colinburn was raised from No. 1 Pit, Candie and

Redford Colliery, where it has a thickness of about 2 ft. It is underlain at a depth of 3 fms. by the Sulphur Coal, with a thickness of about 22 in. At No. 3 Pit, Blackstone Colliery, and in two bores in the vicinity the section of these two coals is somewhat similar. The upper coal was mined on the north bank of the Avon, south of the farm of Hill. There is here said to be 2 ft. 6 in. of good steam coal, with a fair roof and hard pavement.

It is probably the Sulphur Coal which, under the name of Red Coal, formed the lower part of the Bowhouse working. The name in both cases would seem to imply a certain amount of impurity. This is presumably a higher seam than the Sulphur Coal of Armadale, and is more likely to represent the Mid Coal of Craigrigg Colliery, which passes laterally into the Armadale Slatyband Ironstone. The correlation suggested is as follows:—

BONNYHILL.	BOWHOUSE.	CANDIE AND REDFORD.	ARMADALE AND CROFTHEAD.
Highstone Coal.	Speckle Ball Coal.	Colinburn.	Colinburn.
Bonnyhill Craw Coal.	Red Coal.	Sulphur Coal.	Armadale Slatyband.
Lowstone Coal.	...	...	Sulphur or Stinking Coal.
Slatyband.	...	...	Crofthead Slatyband.

Except as regards the highest seam, the correlations given in this table are only tentative.

The evidence adduced above seems to indicate that there may be a fairly wide area of the Bonnyhill Craw Coal still unwrought, though the seam very rarely attains to a thickness workable under present economic conditions. The Sulphur Coal has a more limited area, but the Colinburn is persistent over the east side of the basin, and comparatively little of it has yet been touched.

Musselband Ironstone.—A musselband about 12 fms. above the Slatyband was worked in one of the Beam pits, and has also been proved in some bores further south. The position in the sequence seems too high for correlation with the Highstone; it more likely corresponds to a musselband about 3 fms. below the Armadale Main Coal, which is a constant feature in the Shotts mineral field.

Armadale Main, Gutterhole or Glenfuir Coal.—The name Glenfuir was originally applied to this coal from its having been wrought near Glenfuir House. It is undoubtedly the same as the Main Coal of Armadale, and is now widely known by that name.

In the opinion of the writer it was this coal which was wrought at the old Camelon Colliery, close to Summerford Cottage. Here the section was—

	Ft.	In.
Rock		
Blaes	3	9
COAL	0	9
Blaes (bituminous)	0	3
COAL	0	7
Brown stone	0	3
COAL	1	1
Fireclay		

At the Callendar Coal Company's No. 13 Pit, near Midglen, the section of the undoubted Gutterhole or Glenfuir Coal is sometimes similar, but here a fireclay occasionally takes the place of the blaes above the coal. The seam is wrought by Carron Company at various localities between Shieldhill and Manuelrig. In all these pits, and in the Blackstone Colliery further south, the coal is characterized by either one or two partings, which, however, are not always so thick as in the section given above. The coal is in the main a steam coal. The character of its roof seems very variable.

At Meadowbank Colliery the average section of this coal is inferior to that of the next above it, and at the time of the revision it was neglected. The seam has, however, been mined in the gorge of the Westquarter Burn, which is cut in a massive sandstone that here overlies the coal. The Armadale Main was also wrought from the surface in the Swinedyke plantation. In the Brewery bore at Falkirk the section is—

	Ft.	In.
Sandstone		
FOUL COAL and fireclay	0	6
COAL	2	9
Faky fireclay	2	6
Hard Sandstone		

It is probable that this coal lies intact, and at no great depth, beneath a large part of Falkirk, but the sandy surface deposits, which in the bore referred to are 19 fms. in thickness, would perhaps make sinking to it difficult.

Ball or Brighton Main Coal.—The name Brighton Main was given to this coal at the time when it was the main coal wrought near Brightons. It is, in part at least, identical with the Ball Coal of Armadale, and the latter name is, perhaps, the more general.

Assuming this correlation to be correct, this coal is absent as a workable seam in the western part of the Falkirk coalfield. It is exposed in the railway cutting south of Westquarter House, where it has a thickness from roof to pavement of 4 ft. 6 in., but this includes three partings, which total about a foot. It forms one of the two seams worked at Meadowbank Colliery, where the coal is in two divisions, but without any ironstone. At Manuelrig the section is as follows:—

		Ft.	In.
Brighton Rock			
Blaes		12	0
BALL IRONSTONE	½ in. to	0	4
Blaes		0	3½
BALL IRONSTONE	½ in. to	0	2
Blaes		0	6
COAL		0	3
Foul sclitty COAL		0	6
COAL		0	10
Black bastard fireclay		0	8
COAL		0	10
Coarse fireclay, with occasional large ironstone balls		1	1
COAL		1	5
Bastard fireclay			

The ironstone is no longer of importance, but it was mainly on its account that the seam was at one time wrought near Maddiston. At Blackstone Colliery the section is—

	Ft.	In.
Rock		
Blaes	3	6
Ironstone Balls	0	6
Coal	1	4
Fireclay		

At Crosscroes, Hillfarm Colliery, and also at Armadale, the coal forms one bed with ironstone above. This is the more significant since in two bores quite close to Blackstone Colliery a second thin coal seam occurs 6 and 10 ft. respectively above the one which is wrought. There is also a thinner coal some 2 fms. above the Ball Coal at Armadale. It is thus possible that the latter corresponds only to the lowest division of the Brighton Main Coal, which is formed by the near approach of seams elsewhere more widely separated.

A post of sandstone, known as the Brighton Rock, and 40 ft. thick in Brighton Quarry, lies between this coal and the next in order. This sandstone was also formerly quarried at Manuelrig, and is exposed in the railway cutting at Westquarter, and possibly at the south end of the canal tunnel.

The Mill or Auchingane Coal.—This coal derives its name from Auchingane (Auchingeen on 6-inch map, Stirling, 30 S.W.), where it was formerly worked. It is undoubtedly identical with the Mill Coal of Armadale, although the latter name has not as yet been generally adopted. A "General Section of Strata at Bentend and Auchingean Colliery," dated 1869, gives the following section for this coal, although it is not known exactly from which pit the section was taken.

	Ft.	In.
Blaes	2	8
Clayband Ironstone	0	4
Blaes	0	6
Ironstone, shelly, mixed with blaes	0	6
Parrot Coal, inferior	0	8
Cubical Soft Coal	1	8
Fireclay	0	6

The seam was here wrought partly on account of the ironstone.

The coal was raised from a day level driven into the slope leading up to the canal and railway to the south of Bantaskine House. Here the section was 3 or 4 in. of parrot over 14 in. of "smithy" coal.

The 20-inch Coal, found at the south end of the canal tunnel, is possibly this seam. In the burn which runs past Hall Glen it is 18 in. in thickness, with an overlying "coarse craw coal or blackband ironstone." At Meadowbank Colliery the section is—

	Ft.	In.
Blaes		
Parrot Coal	0	1½
Coal	1	10
"Barney"	0	5
Gas Coal	0	5

At Brighton Quarry—

	Ft.	In.
Rock		
IRONSTONE (impersistent)		
GASSY blaes	1	0
PARROT COAL	0	2
FREE COAL	2	0
Fakes and fireclay	3	0
Brighton Rock		

The Mill Coal has been wrought by Carron Company at Manuelrig and Craigend, and is known to persist as far west as Shieldhill. In all these workings and also at the Muiravonside Colliery the coal preserves its parrot roof, but the blaes above is usually thicker than in the Brighton section. The Mill is commonly a steam coal, but parts of it have been used for household, as well as for gas-making purposes.

A coal described as 2 ft. 1 in. in thickness, with two dirt bands, and 3 in. wild coal atop, was reached in a shaft at Greenhill, a mile and a half south-west of Slamannan, and just north of the Lenzie-Torphichen dyke. This is in all probability the Mill Coal.

Oil-Shale.—A sample from an oil-shale, 4 ft. 6 in. thick, lying a short distance above the Auchingane Coal at the Manuelrigg Collieries, was analysed for the late Mr. J. S. G. Wilson by Mr. D. R. Steuart, chemist to the Broxburn Oil Company, with the following result:—

Crude Oil—16·0 gallons per ton.
Sp. gravity, ·924.
Setting point, 80° F.
Sulphate of ammonia, 9·4 lbs. per ton.

Another sample from the Polmont Burn at Brightons, and presumably on the same horizon, gives—

Crude Oil—19·2 gallons per ton.
Sp. gravity, ·922.
Setting point, 87° F.
Sulphate of ammonia, 9·8 lbs. per ton.

The amount of sulphate of ammonia obtained in these laboratory analyses is only half that got when a large quantity of shale is dealt with.

Low Coxrod or Balmoral Coal.—This coal is 14 in. thick in a bore near Greencraig, and appears to average about a foot over the western end of the basin. On the eastern side it is present, but is usually not more than a few inches in thickness.

A coal wrought at Greenhill, 12 fms. above the seam last referred to, gave the following section:—

	Ft.	In.
Blaes	6	0
Fireclay	0	2
Wild shale	0	8
Blaes	0	2
COAL	1	5
Blaes		

This coal, as well as one of the same thickness, proved in a bore to the north of Middlerigg, was in all probability the Balmoral

Coal. This seam, which is sometimes called the Little Coxrod, must not be confused with the Balmoral of Coatbridge, which is more likely to be the Mill Coal.

Coxrod or Lower Drumgray Coal.—This is the equivalent of the Upper Coxrod of the Carron and Grangemouth field, where the Balmoral Coal is known as the Lower Coxrod. In the Callendar Coal Company's workings it is fairly thick, the section at Mavisbank being—

	Fms.	Ft.	In.
Fakes and sandstone	3	5	0
Foul Coal	0	0	8
Fireclay	0	3	7
Clean Coal	0	2	11
Fireclay	0	0	11

The Coxrod has, however, more commonly a blaes roof. It is a fairly uniform seam without partings, but appears to decrease somewhat in thickness when followed to the south and east. At Craigend it measures 22 in., and at Muiravonside has an average thickness of 24 in.

In contrast to the Upper Drumgray the Coxrod is sometimes named the Soft Coal, and is largely but not invariably raised as a household coal. The main area in which it is present extends from Jawcraig to Candie House, although it is probable that a good deal of the seam within these limits has now been taken out.

A minor area extends from Greenbank to somewhere near Callendar House, on the north side of the fault mentioned in the beginning of this section, p. 64; it will be referred to in the sequel as the Newhouse fault. This was probably the coal found beneath the platform of Falkirk High Station, where it was stated to be 3 ft. in thickness. It was likely a "stoop," and the occurrence has no bearing on the possible amount of the coal still unwrought within the area.

Mid Coal.—This seam has, so far as is known, only been wrought in the eastern end of the Falkirk basin. At Craigend the section is—

	Ft.	In.
Soft blaes	1	6
Coaly sclit	0	9
Blaes	1	0
Coal	0	2
Blaes	0	3
Coal	2	0
Daugh	0	1½
Fakes pavement		

At Gateside Pit—

	Ft.	In.
Rock		
Blaes	0	9
Wild Coal	0	3
Coal	1	8
Faky fireclay		

Further west its development is irregular, and over a wide area it is certainly not a workable seam. In several bores near Greencraig the thickness of the coal varies from 8 in. to 1 ft. 7 in., but in three bores at Rottenstocks it is recorded as 1 ft. 6 in., 2 ft. 2 in., and 1 ft. 5 in. respectively. The last-named figures are, however, probably exceptional. At Gateside Pit the seam has the character of a steam coal.

Splint or Upper Drumgray Coal.—This seam is also known as the Main or Carron Main Coal, as well as the Hard Coal, to distinguish it from the Coxrod or Soft. It varies little in character throughout the district, except where converted into anthracite. In the Falkirk area it is a hard, splinty, or furnace coal, and in great demand as a steam coal, although not anthracitised as in the district to the south.

Like the Coxrod the Upper Drumgray occurs in an elongated area south of Falkirk, bounded on the south by the Newhouse fault. It is well seen above a line of sandstone quarries in the grounds of South Bantaskine House, where it is accompanied by the characteristic musselband, which has been traced a few feet above this coal over almost the whole of the Lanarkshire and Stirlingshire coalfields. During the construction of the Falkirk railway tunnel this coal was met with about 200 ft. from the north-western end, where it was mined by the contractor. The thickness and extent of unwrought coal in this northern area are, however, uncertain.

Southwards the coal does not come on at all extensively to the north of the "Universal Dyke." Beyond this dislocation it extends in an irregular area from Jawcraig to Muiravonside. The section at Craigend is—

	Ft.	In.	
Mussel bed			
Blaes	0	6	
WILD COAL	0	4	
Fakes and sandstone	2	3	
Blaes and balls	0	9	
FREE COAL	0	2	2 ft. 6 in.
SPLINT COAL	1	6	
FREE COAL	0	10	
Fireclay pavement			

The coal retains its fakes and sandstone roof, with or without the intervening blaes, all over the area under consideration: it also preserves a fairly uniform thickness, and was formerly, perhaps, the most important seam of the district. In certain parts of the area it has now, however, been wrought out.

In the Splint Coal workings from No. 24 Pit, Redding Colliery (near Blackbrigs), there is a small but remarkable "want." A bed of soft laminated sand replaces the coal, while the roof of the latter persists above the sand for part of its breadth. In some places fragments of coal remain attached to this roof and project downwards into the sand bed, showing clearly that the coal has been replaced subsequently to the consolidation of the roof of the seam; presumably at some quite recent period. There is no visible connection with the surface and the phenomenon is probably due to the action of underground water, which has eroded the coal and then filled up its channel with alluvial deposits.

Craw or Gas Coal.—A section of this seam at Crosscroes reads—

	Ft.	In.
Rock		
Fakes	1	3
Blaes	1	10
Gas Coal	0	8
„ „ and Ironstone	0	9
Ironstone	0	5
Blaes		

The ironstone is not a constant feature, nor do other records show that the coal in general has a gassy character. The seam appears to have been wrought at one point on the Gardrum Burn. It may also have been this coal which was raised to a small extent under the name of the "Lillie's or Ladygrange Coal" south of Blackbraes Rows, although only 11 in. in thickness. The coal appears to be generally present over the central part of the coalfield, but is only about a foot in thickness. It does not correspond to the Ladygrange, but is more likely the Kiltongue of Lanarkshire.

Miller or Carron Two-foot Coal.—The section in Blackbraes (Forrester's No. 6) Pit was as follows:—

	Ft.	In.
Blaes roof		
Blaes, brushing	1	8
Ironstone	0	5
Coal	0	3
Faky blaes	1	3
Coal	0	10

A musselband very commonly takes the place of the overlying ironstone shown in this section, and can be seen in the Westquarter Burn at Pirleyhill Bridge. The seam was wrought in old crop workings along the Polmont Burn to the south of Redding Muir. The Miller Coal is generally present in the area, but except locally its average section does not exceed a foot of workable coal: it almost certainly represents the Kiltongue Musselband of the Lanarkshire coalfield, and, like that seam, is sometimes associated with an oil-shale, which occurs, for instance, with a thickness of 22 in. above the musselband at Pirleyhill Bridge. Three samples from this locality gave the following analyses:—*

	Oil.	Specific gravity.	Setting point.	$(NH_4)_2 SO_4$
Top sample	25·47 gals. per ton.	·903	96°F.	12·54 lbs. per ton.
Centre sample	14·86 „ „	·918	85°	4·18 „ „
Bottom sample	11·65 „ „	·920	95°	8·36 „ „

Crosscroes and Cockmalane.

Diamond (or Cockmalane) and Wee Coal.—These coals are confined to three restricted areas in the deepest part of the basin, and the Diamond Coal has probably been wrought out. One of these areas, to the south of the Summerhouse "dyke," extends in a narrow strip eastwards from Gardrum for about a mile and a half.

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* These analyses have been kindly communicated by Mr. D. R. Steuart, F.I.C., F.R.S.E.

At the now abandoned No. 8 Pit, Crosscroes Colliery, about 500 yds. N. of Crosscroes, the section was as follows:—

		Ft.	In.
	Rock	6	0
	Soft blaes	0	9
Wee Coal	Free Coal	1	6
	Parrot Coal	0	2
	Free Coal	0	6
	Daugh	0	1
	Fakes and fireclay	6	0
	Diamond Coal	4	0

Both coals were wrought from this pit. Another area lies to the west of Cockmalane. A bore which perhaps passed through a stoop records the Diamond as 3 ft. 5 in. in thickness, while another gives the following section:—

	Ft.	In.
Fakes	9	4
Blaes	1	0
Coal	1	8
Fireclay	0	2
Gas Coal	0	5

The last item being 3 ft. above the Diamond waste. Even if much of the Wee Coal remains intact it is still doubtful whether in such a position it can be wrought to advantage.

The third area in the vicinity of Standrig* was very limited in extent.

There is no reason for doubt that the Diamond and Wee are the equivalents of the coals to which the names of Ladygrange and Virtuewell have been given in the Grangemouth, Carron and Carmuirs coalfields; they can also be correlated with the No. 8 and No. 7 seams of Banknock and Dennyloanhead. It does not, however, follow that they are the Ladygrange and Virtuewell of Lanarkshire. It seems equally probable that each represents a portion of the Lanarkshire Virtuewell.

Future of the Coalfield.—In contrast to the district of Slamannan, the Falkirk coalfield shows little present prospect of exhaustion. In the former area, after the working out of the four principal seams, little remained in the nature of a reserve. In the Falkirk area the most profitable seam—the Diamond—occupied only a small area from which it has all been removed. The two coals next in order of importance are the Splint and the Coxrod, and in these considerable inroads have already been made. The Falkirk field, however, differs from that to the south in the presence of a series of thinner coals and of seams whose partings make them less profitable subjects. These thin coals have been wrought at the crop and also where near the surface, but not much, up to the present time, in the deeper portions of the field. It is likely that coal-cutting machinery, as well as the exhaustion of certain other Scottish coalfields, will bring these thinner seams more into prominence. There is thus every reason for confidence as to the future of this coalfield.

Structural Features.—Reference has already been made to the presence of the Armadale Main Coal in the Swinedyke plantation north of Lauriston. The southerly dip of the strata at this point would, if continued northwards, soon bring to the surface the underlying seams. It is therefore not likely that much workable coal extends beneath the Carse in this direction.

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* New Statistical Account of Scotland. County of Stirling, 1845, p. 209.

The probable presence of the Armadale Main Coal beneath the town of Falkirk has also been indicated. Southwards the higher seams up to the Splint Coal come on before the Newhouse fault is encountered. Even if the Splint and Coxrod Coals have been wrought out within this area the lower seams will remain, and a bore put down in the south-western part of Callendar Wood would almost certainly prove the position both of the Armadale Main and of the overlying Mill Coal.

The Newhouse fault is believed to have a throw of 30 fms. near the locality of that name. Eastwards its position and amount are uncertain. About a mile to the south of this dislocation is the so-called "Universal Dyke," another east-and-west fault, with downthrow to the south, which appears to have received its name from its persistence. It extends westwards from Maddiston to a point some distance west of Wester Glen. North of Shieldhill the throw of the fault is 15 fms., and probably does not ever much exceed this figure. Referring to the raised area between these faults the New Statistical Account of Scotland * speaks of "the toils of the borers being spent in vain on a mass of unfathomable sandstone." The Coxrod Coal has, however, since been wrought in one or two parts of the ground referred to, and the rest forms a likely field for exploitation of the lower seams. The Armadale Main, Ball and Mill Coals must all be present, and have only been worked to a small extent within the area.

The deepest part of the Falkirk coalfield lies to the south of the Universal Dyke. In common with the area to the north, it is intersected by various north-westerly faults, which are sufficiently indicated in the published maps, and do not call for further description. It may, however, be noted that these lines of disturbance, while not always inferior in amount of throw, seem less persistent than those whose trend is east and west. Among the latter the Summerhouse "Dyke" has already been mentioned. It runs from Summerhouse to Muiravonside, with a downthrow to the south which at one point amounts to 17 fms. Its course is parallel to that of three intrusive dykes of dolerite, whose relations are shown in Fig. 4. The most northerly is known as the Craigend Whin, and can be followed for several miles to the east of that locality. In the eastern part of its course it is not accompanied by any appreciable displacement, but near Craigend there must be a downthrow of at least 15 fms. to the south along the line of the intrusion. The whin dies out somewhat west of Craigend, its line being continued by a fault with the same direction of throw. The central dyke shows no displacement, but the southern intrusion is related to a fault (throwing north) in much the same manner as the Craigend Whin. This dyke is called the Craigmad Whin; it can be traced for some 10 miles to the west, and, for the rest of its course, is not accompanied by any displacement. It seems probable that these three dykes are connected in depth, and that the intrusion has been deflected to north and south respectively by the two flanking faults shown in the diagram. The fact that the

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* New Statistical Account of Scotland, 1845, vol. viii. p. 209.

Summerhouse fault has not been followed in any part by the dolerite suggests that this displacement was later, while the flanking faults were earlier, than the period of intrusion.

Yet another dolerite dyke runs parallel to the Craigmad Whin at a distance of about a mile to the south. Near Jawcraig it splits, apparently into three branches, of which the southernmost is the most persistent, running completely across the coalfield into the area to the east. Near Candie End this branch is accompanied by a downthrow to the south amounting to something like 20 fms.

These dolerite dykes are all of moderate thickness, and have been locally quarried where not covered by surface deposits. They are not at present extensively wrought for any purpose.

The only other dislocation to which reference need be made is the Gateside fault, which runs from near Blackbrigs at least as far as Netherton, with a downthrow to the south which at one point amounts to 30 fms.

A belt of country about which comparatively little is known lies to the north-west of the larger area in which the Coxrod Coal has been worked. The Auchingane Coal is, of course, present in a part of this field, and could, no doubt, be found elsewhere by boring. A coal was raised at the "Greenrig" Pit, situated probably by the roadside, 700 yds. E.N.E. from the farmhouse of that name. Here the section was—

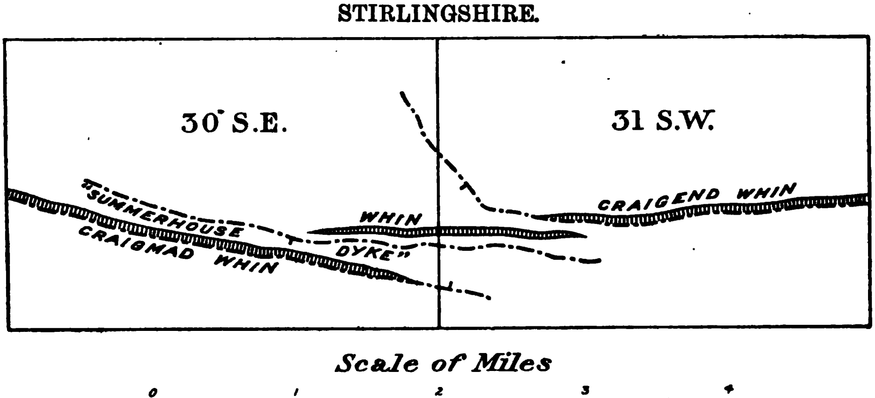

FIG. 4.—Diagram showing relations of Faults and Dolerite Dyke-intrusions in the Falkirk Coalfield.

Fireclay roof	
COAL	2 ft. 6 in.
Freestone pavement	

From the thickness of the seam it is probable that this was the Armadale Main Coal. Two bores to the west of Auchingeen record 1 ft. 11 in. and 2 ft. 7 in. of coal respectively. If these figures are correct, they show that the Armadale Main Coal is present in fairly good form over a considerable part of this western area.

In a bore 500 yds. west of Laigh Stanerig the Mill Coal was only 10 in. and the Armadale Main Coal only a foot in thickness, but as the latter of these seams is not known in the Slamannan coalfield this attenuation is not remarkable, and it follows that the group of coals below the Balmoral must decrease in thickness to the south and west. There is consequently little prospect of coal in paying quantities being found in the immediate neighbourhood of Slamannan—at least so far as Coal Measure coals are concerned. The presence of the Balmoral Coal at Greenhill, to the north of the Lenzie-Torphichen dyke, has already been noted: its occurrence there is due as much to the rising ground as to any change in the inclination of the strata.

Immediately south of the North British Railway, a mile to the east of Slamannan, a pit was sunk to a "coarse gas coal": this seam cannot now be identified. It is probable that eastwards along the southern margin of the basin the Armadale Main, Ball and Mill Coals once more increase in value. A trial pit was sunk to the Mill Coal about half a mile north of Avonbridge, while further east, near Blackstone, all three are workable subjects. Along the eastern margin of the basin, as already described, these coals are largely worked; there are, in addition, areas of the underlying Colinburn and Sulphur Coals which will no doubt in the future come to have a greater importance than at present. E. M. A.

The Slamannan Coalfield.

(Area South of the Lenzie-Torphichen Dyke.)

(Stirling, 35 N.W., N.E.; 36 N.W.; Linlithgow, 4 S.E.)

The Coxrod, Splint, Ladygrange and Johnstone Coals together at one time formed a mineral field of considerable wealth, but are now unfortunately exhausted. The thinner underlying seams offer for the present little prospect of a revival of activity in this district, which is as a result becoming largely depopulated.

The following is an average section:—

		Thickness.			Depth.		
		Fms.	Ft.	In.	Fms.	Ft.	In.
Strata							
JOHNSTONE OR VIRTUEWELL COAL	OIL-SHALE	0	0	6			
	IRONSTONE	0	0	2			
	COAL	0	2	6	19	0	0
Strata							
LADYGRANGE COAL		0	2	6	28	0	0
Strata							
COAL		0	1	0	30	0	0
Strata							
KILTONGUE MUSSELBAND	MUSSELBAND IRONSTONE	0	0	2			
	OIL-SHALE	0	0	6			
	MUSSELBAND IRONSTONE	0	0	4			
	Blaes	0	0	4			
	COAL	0	0	5	35	0	0
Strata							
KILTONGUE COAL		0	0	9	42	0	0
Strata							
MUSSELBAND		0	0	6	51	0	0
Strata							
SPLINT COAL		0	2	0	52	0	0

	Thickness. Fms.	Ft.	In.	Depth. Fms.	Ft.	In.
Strata						
COXROD COAL	0	2	0	65	0	0
Strata						
BALMORAL COAL OF SLAMANNAN	0	1	6	70	0	0
Strata						
MILL OR AUCHINGANE COAL	0	1	0	81	0	0

The strata for 35 fms. below the Mill position have been proved by a bore from the bottom of No. 1 Pit Binniehill. The only coal seam worthy of notice is in a blind condition from the influence of the whin float which is known to underlie this coal field. The coal is 1 ft. 1 in. in thickness, and lies 26 fms. below the horizon referred to. It has been correlated with the Colinburn Coal of Armadale, but there is not the necessary agreement between this and other bores to make this correlation at all reliable.

The Mill Coal, though thin, appeared to be fairly constant. It was 1 ft. 2½ in. in thickness in the Binniehill bore, but has not been wrought to the south of the dolerite dyke.

Balmoral Coal of Slamannan.—This seam is sometimes thicker than the figure given in the section, but is not supposed to be of good quality. It was wrought to a small extent at a pit near Limerig, and possibly also elsewhere within the area. The bore at Binniehill gives—

	Ft.	In.
BITUMINOUS SHALE	0	9½
BLACKBAND IRONSTONE	0	3
COAL, clean	2	6
POOR BLACKBAND IRONSTONE	0	7

This coal must not be confused with the Balmoral of Coatbridge and Greengairs. The latter is probably the Mill or Auchingane Coal, while the present seam corresponds more likely with the Shotts Gas.

The Coxrod or *Lower Drumgray Coal* was a smithy* or household coal, but has been largely wrought out within the district. A part is left on the eastern margin of the coalfield but is much affected by the underlying whin. At Arnloss some attempt was made to work it for anthracite. "Although the analysis showed 87 per cent. of carbon, the physical condition of the coal was bad, being sooty and lustreless. It was also very soft, and was thus of limited commercial utility."† The coal was wrought on a small scale at No. 7 Pit Barnsmuir Colliery, where it measured 1 ft. 4 in. to 1 ft. 6 in. in thickness. Otherwise it is still intact to the east of the Black Loch and south of the Limerig dyke. A bore near Easter Whin proved this coal to be 1 ft. 4 in. in thickness at a distance of 28 fms. above the dolerite; another near Stonerig found it 1 ft. 6 in. 39 fms. from the whin. It seems therefore probable that a square mile or so of the coal in this neighbourhood has remained unwrought not on account of deterioration but because of the thinning of the seam.

Splint or *Upper Drumgray Coal.*—The Splint Coal of this district shared the reputation of that to the west as a first-class navigation or steam coal, although not mainly converted into anthracite. This seam has been almost entirely exhausted, and at the time of the revision was only being wrought at one locality, near Arnloss. Here it was found to persist for some distance with no covering but boulder-clay, and owing to its splinty character was so little softened by weathering that it was actually being worked under these conditions. It is overlain, as in other districts, at a distance of a few feet by a band of *Carbonicola robusta,* or "musselband," in association with a layer of somewhat bituminous shale.

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* A smithy coal is one which forms a coke consisting of small pieces; in other words, a "char."

† Dron, "The Coal-Fields of Scotland," 1902, p. 158.

The *Kiltongue Coal* is too thin to be workable, but an attempt was at one time made to work the *Kiltongue Musselband,* partly on account of the oil-shale associated with the seam. The *Ladygrange* was a household coal, but has been entirely wrought out. The latter observation applies also to the *Johnstone* or *Virtuewell Coal,* which was a first-class household coal, while the overlying shale was distilled in retorts specially erected for the purpose.

Noticeable wants occurred near Limerig in the Virtuewell and Splint seams. In both cases these were elongated so as to suggest stream erosion, that in the Virtuewell running south-east, the other a little south of east. The latter has been traced for about two miles, the beds which elsewhere form the roof and pavement coming together where the coal has disappeared. In neither case was there any trace of the want in the underlying or overlying seam.

IGNEOUS ROCKS.

The Lenzie-Torphichen dolerite dyke which forms the northern limit of the coalfield is accompanied by an upthrow to the north which takes off the principal seams. Near Greenhill there is a small area of Balmoral Coal to the north, which enables the throw to be estimated at about 40 fms. Elsewhere the amount is quite uncertain.

It is probable that the whole of the Slamannan coalfield is underlain by a sill (float) of dolerite which is proved to be 40 fms. in thickness in the bore near Stonerig. Its presence is indicated by the blind coal and other items in the bore from Binniehill Pit bottom. At this point the sill lies more than 50 fms. beneath the Coxrod, which in consequence is unaffected by the intrusion. Its horizon gradually rises to the east and south, and this transgression, along with the general rise of the strata in that direction, brings it to the surface near Avonbridge. Thence the outcrop extends as far as Westcraigs, forming a line of low hills. Its change of level is expressed in the fact that the Coxrod becomes unworkable near Arnloss; it is also shown by the two bores at Stonerig and Easter Whin. Hence it is not surprising that at Westcraigs the intrusion has risen high enough in the metals to overlie by some distance the Splint or Upper Drumgray position.

Northwards the outcrop of the dolerite ends abruptly along the line of the Lenzie-Torphichen dyke, and at one point can be seen to become finer towards a vertical margin. Further east the Torphichen sill terminates sharply along a continuation of the same line. The difference in level of the two sills cannot be explained by faulting, since what faulting there is would tend to produce displacement in an opposite direction. It may rather be inferred that the Lenzie-Torphichen dyke rose along a pre-existing fault line, and gave off floats on different levels on its opposite sides. That on the north is both relatively and actually lower, as may be seen by the surface position of the two sills. This point is also shown by comparing the levels in the bore from Binniehill Pit bottom (which must have made a near approach to the dolerite, see p. 79) and in the deep (1907) Rashiehill bore, in which the sill is at least 100 fms. further beneath the surface. The only other important intrusion is the Bedlay-Greengairs east-and-west whin dyke which passes close by Limerig. From the county boundary its easterly course can be traced, with the mining information available, as far as Little Black Loch. Near Barnsmuir it was cut in the Splint Coal workings, and was found to have a thickness of about 30 yds. As a rule the dyke seems to cause no appreciable difference of level. Near Little Black Loch this dyke crosses the line of a thinner intrusion which can be traced south-south-westwards in the Splint Coal workings as far as the North Calder Water.

North-westwards of the Black Loch the coalfield is intersected by several north-westerly faults. The largest of these, the Lodge "Dyke," appears to cross the Bedlay-Greengairs intrusion without interruption. A fault running parallel to it is, however, deflected, and perhaps continues on a different line upon the southern side. The biggest of these faults throw north-east, or contrary to the general dip of the strata. Their effect is thus to bring and keep in the two highest seams, which otherwise would not have been present in the Slamannan coalfield.

As the Coxrod Coal was unwrought in the eastern part of this coalfield it has been found impossible to trace its outcrop. One or two thin coals which are probably below this horizon can be seen along the course of the Drumtassie Burn. The thickest measures only a foot, and is besides too much burnt to be of value.

The dolerite sill to the south of Avonbridge was wrought as recently as 1906 by the Avonbridge Granite and Whinstone Company, in three quarries for the production, chiefly, of setts and kerbs, the refuse being broken up for road metal. Of the latter, 2000 tons a year is said at one time to have been produced; this could be delivered in Falkirk and Bathgate at five shillings a ton. The westernmost quarry (Craigend) is historically interesting, having been opened in 1836 to provide "sleepers" for the railway from Airdrie through Slamannan to Causewayend (on the Union Canal) which was then under course of construction. These sleepers were square blocks measuring 2 ft. × 2 ft. × 1 ft.; they were, however, found to be too "jolty," and were discarded in favour of the present wooden article.

The rock varies in texture, that of the middle quarry being on the whole the coarsest in grain. The coarser material was machine-broken when used for road-metal, while the hand-breakers preferred the "cleaner" or finer-grained variety.

The rock in all three quarries is so widely jointed as to permit the formation of channels and kerbs. This is also a distinctive feature of the two quarries to the north-west of Muckraw, which were on this account widely known, although the material was somewhat softer. Some of the rock from this locality is stated to have been exported to Germany. The Avonbridge sill, as stated on the previous page, is limited to the north by a vertical junction, but the available supply is far from having been exhausted.

We conclude this chapter with the following general section of the East Stirlingshire (Falkirk, Carron and Airth) Coalfields.

	Thickness.			Depth.		
	Fms.	Ft.	In.	Fms.	Ft.	In.
WEE COAL (Falkirk) or VIRTUEWELL COAL (Carron and Airth)	0	2	0			
Strata						
DIAMOND or COCKMALANE COAL (Falkirk) or LADYGRANGE COAL (Carron and Airth)	0	3	0	3	0	0
Strata						
Kiltongue Musselband				17	4	0
MILLER COAL (Falkirk) or TWO-FOOT COAL (Carron)	0	2	0	18	0	0
Strata						
CRAW or CROW COAL of Stirlingshire = KILTONGUE COAL of Lanarkshire	0	2	0	26	0	0
Strata						
MUSSELBAND				33	0	0
SPLINT or HARD COAL (Falkirk) or CARRON MAIN COAL = UPPER DRUMGRAY COAL of Lanarkshire	0	3	0	34	0	0
Strata						
MID SPLINT COAL (Airth) = MID COAL (Craigend)	0	1	6	39	0	0
Strata						
UPPER COXROD (Carron and Airth); COXROD or SOFT (Falkirk) = LOWER DRUMGRAY COAL of Lanarkshire	0	2	6	47	0	0
Strata						
LOW or LOWER COXROD COAL	0	2	0	50	0	0
Strata						
MUSSELBAND				56	0	0
Strata						
MILL or AUCHINGANE COAL	0	2	0	61	0	0
Strata						
BALL or BRIGHTON MAIN COAL	0	2	0	67	0	0
Strata						
ARMADALE MAIN or GLENFUIR COAL	0	2	6	73	0	0
Strata						
COLINBURN COAL	0	1	6	82	0	0
Strata	3	3	9	85	3	9
BONNYHILL CRAW COAL	0	1	0	85	4	9
Strata	1	0	0	86	4	9
LOWSTONE (ironstone balls in blaes with marine fossils)	0	0	6	86	5	3
Blaes	0	1	0	87	0	3
LOWSTONE COAL	0	1	0	87	1	3
Strata	1	5	0	89	0	3
Fireclay	1	0	0	90	0	3
SLATYBAND IRONSTONE	0	3	0	90	3	3

Synonyms, etc.—The New Brighton, Victory, Bowhouse and Highstone Coals were all probably equivalents of the Colinburn. The Bonnyhill Crow and Lowstone Coals come between this horizon and the Slatyband position in one part of the Falkirk coalfield, as also does the Sulphur Coal of Blackstone. The so-called Ladygrange Coal of Carron and Airth may not be the seam so named in Lanarkshire, but a portion of the Virtuewell. E. M. A.

Wester Glentore.

(Lanark, 3 N.W., N.E.)

In the narrow strip of Coal Measures, south of Fannyside Muir, that falls within this area, the following lower seams are present.

The Coxrod or Lower Drumgray, 13 fms. below the Upper Drumgray. This seam, 9 to 14 in. in thickness, has been wrought from a pit between Bridgend and Easter Glentore. The coal is burnt in the neighbourhood of the dyke to the north.

The Blacktongue Plantation Coal, 6 to 18 in., 3–4 fms. below the Coxrod: the outcrop is seen on the roadside at the west end of the plantation.

Separated from this seam by 3–4 fms. of sandstone and blaes and ironstones, occasionally with mussels, is a coal 9 to 19 in. thick, which outcrops on the east side of the stream between Shiels and Loanhead.

The Smithy Coal (often with a thin rib of parrot coal), 11 to 26 in. in thickness, was in recent years worked at Wester Glentore Colliery, and in earlier times from a dry level at the roadside near Shiels.

For further details concerning the coals of the Greengairs coalfield see Memoir on Part V., p. 112. L. W. H.

CHAPTER V.

SUPERFICIAL DEPOSITS.

Carse of Kinneil.

THE superficial deposits of the Carse and of the small part of Area II. that lies east and south-east of Inveravon, include raised beach and estuarine material together with earlier glacial sands and gravels and boulder clay.

The whole surface of the Carse is probably formed either of raised beach and estuarine deposits or of alluvia of a closely similiar character which have been laid down by flood waters in recent times. The highest beds are for the most part clays or muds closely similar to those forming the extensive tidal flats along the southern shore of the Firth of Forth.

Most of the surface of the Carse is from 2 to 4 ft. above ordinary high-water-mark, and certain parts, furthest away from the sea, are considerably higher: little or none, however, of the surface reaches the level of the "25-foot" raised beach, which in the Bo'ness district may be as much as 35 to 40 ft. above ordnance datum level.

The floods that from time to time cover parts of the Carse are said to be chiefly due to land water, since it is only when the sluices on the drains are not in working order that extra high tides can flood the comparatively small tracts behind the embankment that lie below high-water-mark.

Agriculturally the Carse soils are unusually valuable, partly perhaps on account of the presence in the clays of some amount of finely divided organic matter. They produce excellent crops of wheat and beans, and afford good pasturage of cattle, which perhaps derive some benefit from the presence of a certain amount of salt in the soil.

From time to time it has been proposed to enclose the tidal flats to the north of the Carse.*

Falkirk District.

The Carse lands to the north-east of Falkirk are mainly formed of the sandy deposits of the latest or "25-foot" raised beach. The upper limit of deposition here rises to 40 ft. but falls eastwards to the 22-ft. level.

The southern limit of these marine deposits is an old sea margin, usually well-defined. Beyond this margin lies a belt occupied by mounds and ridges of sand and gravel extending from Bonnybridge to beyond the eastern limits of the present area. These accumulations are of glacial origin, and were probably laid down along the landward margin of a mass of ice which occupied the estuary of the Forth towards the close of the Glacial Period.

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* Report of the Royal Commission on Coast Erosion, vol. iii. 1911, part V., p. 132. See also H. M. Cadell, "The Story of the Forth," Glasgow, 1911, Chaps. XII. and XIII.

There are one or two small sand pits in these deposits near Polmont, and the clay wrought in and around Grahamston is believed to have a similar origin.

The southern limit of these gravels coincides for some miles with the conspicuous and well-known Polmont Kame or Esker.

The remainder of the ground to the south is covered with boulder clay, often arranged in "drumlins"—long ridges having a definite direction, in this area generally a little to the north of east.

The Carse deposits produce rich agricultural land, but from the mining point of view are often an obstruction, owing to the difficulty of sinking through the loose material of which they are composed.

E. M. A.

BURIED RIVER CHANNELS.

The occurrence of a deep pre-glacial channel filled with superficial deposits to a depth of at least 40 fathoms in the Carron coalfield, and its effect on the position and course of the coal crops, has already been referred to in Chapter IV., p. 62.

The course of this buried river channel has been followed in a number of bores: it extends along the present valley of Bonny Water and thence along that of the Carron, entering the Forth a few hundred yards to the north of Grangemouth Harbour.

The depth of the old channel to rock-head at Carronbank is 285 ft., and at Towncroft, three-quarters of a mile further down the river, 252 and 273 ft. in two adjoining bores. The breadth of the ancient valley at Carronshore is about 1000 yards: elsewhere it does not appear much to exceed 500 yards.

The Carron channel has been described in detail by Dr. Croll in a paper contributed in 1869 to the Edinburgh Geological Society;* it is also referred to by Mr. Cadell in his "Story of the Forth,"† where the reader will find a useful section (p. 86) showing the form of the channel and its relation to the coal-seams at Carronshore.

L. W. H.

PEAT.

There are extensive areas of peat in the southern part of Falkirk and the northern part of Slamannan Parish. These include Garbethill Muir, and a connected area known in part as the Darnrig and in part as the Gardrum Moss. One bore in Darnrig Moss shows the peat to be no less than 30 ft. in thickness.

At the time of the revision (1907) a new industry had recently been established in this district, where the Griendtsveen Moss Litter Co., Ltd., had leased the Gardrum and neighbouring peat-mosses for the manufacture of moss litter and material for packing fruit and vegetables. The employees were all Dutch, who, under favourable weather conditions, could earn as much as £3 per week. The material used was the loose brown peat which forms the upper part of the moss. This was dug out, placed in stacks, and air dried, being afterwards compressed by mechanical means into bales suitable for transport.* The work has now been discontinued. E. M. A.

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* "On Two River Channels Buried under Drift," *Trans. Edin. Geol. Soc.*, vol. i., 1869, p. 330.

† *Op. cit.*, p. 84.

A wide area of peat-covered ground extends from the head of the Avon Water northwards across Fannyside Muir to Arns and Garbethill and is continued towards the north-east in the peat mosses of Garbethill Muir.

On either side of the head of Fannyside Loch the peat has been extensively bored with a view to its use for moss litter and packing, for which purposes the upper layers of brown peat seem very suitable.

To the east of Blackmyreknoll the depth of the peat varies from 19 to 27 ft., and an average section from a large number of bores shows—

	Ft.
Fibrous brown peat of excellent quality for moss litter . .	7–10
Brown peat, less fibrous, suitable for packing	3
Hard black peat	9–14

Pavement hard boulder clay or disintegrating sandstone. On the north-west side of Fannyside Loch the average section gives—brown peat, 6 ft.; black peat, 8 ft. L. W. H.

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* J. S. Grant Wilson, "Summary of Progress for 1907," *Mem. Geol. Survey*, 1908, p. 110.

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